DISEASES OF NUTRITION AND INFANT FEEDING

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DISEASES OF NUTRITION AND INFANT FEEDING

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New York

THE MACMILLAN COMPANY

1915

Set up and electrotyped. Published, September, 1915.

Norwood Press:
Berwick & Smith Co., Norwood, Mass., U.S.A.

PREFACE

This book was written to meet what seemed to the authors to be two distinct needs in American pediatric literature; a detailed description of the scientific basis of rational infant feeding and a description of the method of infant feeding taught in the Harvard Medical School. In it the authors have endeavored to meet these needs. It is intended to satisfy the demands, on the one hand, of those students who wish to become acquainted in the original with the data on which the scientific basis of infant feeding rests and, on the other, of the general practitioner who wishes to learn the clinical and practical sides of infant feeding. It is hoped that it will not only point the way to further investigations but also be of service to the clinician in his daily work.

John Lovett Morse
Fritz B. Talbot

Boston,
September, 1915.

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DISEASES OF NUTRITION AND INFANT FEEDING

SECTION I

PHYSIOLOGY AND METABOLISM

CHAPTER I

PHYSIOLOGY OF DIGESTION

MOUTH

Food is drawn into the mouth of the infant by the negative pressure which results from the act of sucking. This negative pressure is between five and fifteen cubic centimetres of mercury or between ten and one hundred and forty cubic centimetres of water.[1]

Almost all the work on the reaction of the oral cavity has been done by older writers and, although their results have not been uniform, it seems to be established that the reaction of the mouth of the new-born infant is neutral or weakly alkaline before the first food is taken. The acid reaction of the mouths of older babies is probably due to the breaking down of food remains. Oshima [2] has recently demonstrated lactic acid, by Uffelmann's test, in the mouths of infants, most often between the ages of three and six months. He attributes the presence of this acid to the action of a leptothrix. Immediately after birth a baby's mouth is free from bacteria, but it very quickly becomes infected.

The weight of the salivary glands at different ages, as given by Berger,[3] is as follows:

TABLE 1

Age	*Average body weight*	*Parotid*			*Av. wt. both sub-maxillaries*	*Av. wt. both sub-linguals*
		Av. wt.	*Max. wt.*	*Min. wt.*		
New born	3580 gm.	1.80	2.4	0.9	0.84	0.42
3 months	3600 gm.	3.18	4.8	1.4	1.53	0.84
6 months	4745 gm.	4.50	5.8	3.1	2.12	1.05
2 years	9100 gm.	8.60	9.6	8.2	4.89	2.00

[1] Gundobin: Die Besonderheiten des Kindesalters, Berlin, 1912, 248.
[2] Oshima: Arch. f. Kinderh., 1907, xlv, 21.
[3] Quoted by Gundobin: Die Besonderheiten des Kindesalters, Berlin, 1912, 258.

These glands are heavier in healthy and well developed than in sickly and poorly developed infants, but considerable individual variations are often found. The glands begin to differentiate from the epithelium of the mouth in the second month of fetal life and can be dissected at the tenth week of fetal life.

Saliva is secreted during the first week of life and probably during the first day (Joerg, Bidder and Schmidt). It has the power of converting starch into sugar as soon as it is secreted.[1, 2, 3, 4] Ptyalin is present in both the parotid and submaxillary glands,[3] Ibrahim was able to demonstrate diastatic ferments in both the parotid and submaxillary glands of two fetuses. One of them weighed but 150 gm.; the other was in the sixth month of fetal life. He thought that there was about the same amount in each gland at birth. The diastase in the saliva is only able to digest starches as far as maltose and not into grape sugar.[5, 6, 7] Shaw[8] gave babies a test meal of barley water and washed out their stomachs from fifteen to sixty minutes later. He found that it was possible for the diastatic action of saliva to continue in the stomach as long as two hours after feeding. It is difficult to say what rôle the saliva of infants plays in the physiology of digestion. Probably it plays a very small part. In general, it has been shown,[9, 10, 11, 12, 13] that the dryer the food, the greater the secretion of saliva. This rule, however, does not hold good with milk,[14] the food of babies, because considerably more saliva is secreted for a food containing milk than for that containing meat. It is admitted,[15] [16] however, that saliva may cause coagulation of milk and thus help stomach digestion. The amount of water, albumen, and mucus in saliva varies considerably.

[1] Schlossmann: Jahr. f. Kinderh., 1898, xlvii, 116.

[2] Montague: Diss., 1899, Leiden; Montague: Centralbl. f. Inn. Med., 1900, xxi, 705.

[3] Schilling: Jahrb. f. Kinderh., 1903, Neue Folge, lviii, 518.

[4] Moll: Monatsschr. f. Kinderh., 1905–06, iv, 307.

[5] Musculus and Gruber: Zeitschr. f. Phys. Chem., 1878, ii, 177.

[6] Musculus and Mering: Zeitschr. f. Phys. Chem., 1878, ii, 403.

[7] Hamburger: Pfluger Arch., 1895, lx, 543.

[8] Shaw: Albany Med. Annals, Jan., 1904, xxv, 148.

[9] Glinsky: Sitzung d. Gesellsch. russ. Ärzte zu. St. Petersburg, 1895.

[10] Wulfson: Diss. St. Petersburg, 1898.

[11] Snarsky: Diss. St. Petersburg, 1901.

[12] Malloizel: Jour. d. Physiol. et Pathol., gener., 1902, 547.

[13] Heymann: Diss. St. Petersburg, 1904.

[14] Sellheim: Diss. St. Petersburg, 1904.

[15] Billard and Dieulate: Comptes rend. de la soc. de biol. à Paris, 1902.

[16] Borissow: Russk. Wrat. 1903, Die letzen 8 Arbeiten, quoted in Nothnagel's Handbuch.

Finizio [1] induced infants to suck bits of cotton and then determined the amylolytic power of the saliva. This was greatest about midday and was different in babies of the same age. When the babies were less than six months old, it did not vary after nursing or when starch was added to the food, but when they were over six months old, there was an increase in the amylolytic power immediately after a meal containing starchy foods. This increase was still noticeable an hour later. Beginning at about six months there seemed to be a gradual development of the specificity of function of the salivary glands. He tested the saliva of several babies monthly during the first year and found that the amylolytic power increased progressively from birth to the age of twelve months. At eight to ten months it was twice that at birth, and at one year a trifle less than that of children two to three years old. Allaria [2] found that, after the first weeks of life, the mouth reacted acid to litmus paper phenolphthalein, and that the reaction was rarely neutral or alkaline.

STOMACH

The stomach of the fetus lies completely in the left hypochondrium, with the exception of the pylorus, which is in the median line and is completely covered by the liver. These relations change after birth so that at fifteen months the liver no longer overlaps the stomach. The position of the stomach of the fetus is nearly vertical. In the newly-born child, it lies somewhat obliquely in the abdomen, and at the end of infancy, it has almost reached the transverse position.

The growth of the fundus compared with that of the stomach as a whole is relatively rapid during infancy. The length of the fundus of the fetus is $^1/_5$, of the infant $^1/_4$, and of the adult $^1/_3$ of the total length of the stomach.[3]

The stomach, as would be expected, grows rapidly in size during the first year. The greater curvature becomes longer, increasing 16 to 24 centimeters in length. Pisek and Lewald [4] conclude from their investigations with the Rœntgen ray that there is no characteristic normal type of stomach in the infant. It is horizontal rather than vertical when compared with the adult type, and follows certain rather definite forms. They distinguished (a) the ovoid or Scotch bag-pipe type of Flesh and Peteri (b), the tobacco

[1] Finizio: Rev. Hyg. et Med. Infant, viii, No. 3, 224.
[2] Allaria: Monatsschr. f. Kinderh., x, No. 4, 179.
[3] Gundobin: *loc. cit.*, 264.
[4] Pisek and Lewald: Am. Jour. Dis. Children, 1913, vi, 232.

pouch (retort shape of Alwens and Husler), and (c) the pear-shaped stomach with base above and to the left. The shape of the stomach does not depend on the amount or character of the food ingested, but rather upon the quantity of gas which it contains or acquires. Major [1] showed that the shape of the Rœntgen ray picture of the stomach varied with the position of the infant and that the movements of the diaphragm could cause changes in its appearance. Alwens and Husler (quoted by Pisek [2]) report, furthermore, that they have observed a change in the form from the tobacco pouch to the bag-pipe variety after the intestines have been emptied.

Gastric Capacity.—Recent investigations show that the anatomic gastric capacity, obtained by measuring the capacity of the stomach by water poured in post mortem at a pressure of 15 cm. (the figures given in most text-books are based on such observations), is considerably smaller than the physiologic capacity. The physiologic capacity of infants' stomachs is at such variance with the anatomic measurements that it is safe to say that a baby can digest more than the anatomic size of the stomach would seem to warrant.[3]

The following figures were taken from Pfaundler,[4] and represent the gastric capacity post mortem with a pressure of 15 c. c. water.

TABLE 2

Age of infant	*Months*							
	1	2	3	4	6	8	10	12
Systolic stomach..........			210	235	290	360	430	490
Diastolic stomach........	150	175	200	230	295	365	445	515

The gastric capacity, determined post mortem by Holt,[5] is as shown by table 3 on page 5.

Tables 2 and 3 represent the gastric capacity of infants with closed pyloric valves which allowed no food to escape into the intestine. Mosenthal investigated the gastric capacity of infants during life (physiological capacity) and post mortem (anatomic capacity), and found that the former was always larger

[1] Major: Zeitschr. f. Kinderh., 1913, viii, 340.
[2] Pisek and Lewald: *loc. cit.*
[3] Mosenthal: Arch. Ped., 1909, xxvi, 761.
[4] Pfaundler: Magencapacitat im Kindesalter: Stuttgart, 1898, quoted by Gundobin.
[5] Holt: Dis. Infancy and Childhood, N. Y. and London, 1911, 309.

TABLE 3

Age	No. of cases	Capacity oz.	Capacity c. c.	Age	No. of cases	Capacity oz.	Capacity c. c.
Birth	5	1.2	36	7–8 mos.	9	6.88	200
2 weeks	7	1.5	42	10–11 mos.	7	8.14	244
4 "	4	2.0	60	12–14 mos.	10	8.90	265
6 "	11	2.27	68				
8 "	4	3.37	100				
10 "	2	4.25	128				
12 "	6	4.50	132				
14–18 wks.	12	5.00	150				
5–6 mos.	14	5.75	172				

than the latter. The following table is a summary of the results which he obtained in a study of twenty-four cases:

TABLE 4

Amount of milk offered at each nursing	4.0 oz.
Amount of milk ingested at each nursing	3.6 oz.
Post mortem gastric capacity (Pfaundler's method)	2.6 oz.

"In every instance, excepting the diastolic stomachs, the infant ingested more fluid at a nursing than the volume of its stomach, as determined by careful measurements, can contain." This means that the figures for gastric capacity given above represent the anatomic capacity of the stomach, and that the physiologic capacity, what an infant can take at a nursing, can be considerably larger than this. This can be explained by the fact that shortly after milk is swallowed the stomach shows signs of motor activity and the milk begins to pass almost immediately into the intestines. This is proven by fluoroscopic examination which shows the milk spurting through the pylorus into the intestine before the meal is finished. This happens more easily with human milk than it does with simple dilutions of cow's milk.

Duration of Stomach Digestion.—The duration of stomach digestion has been studied for a long time, at first with the stomach tube,[1, 2, 3, 4, 5] only, and recently with the Rœntgen ray.[6, 7] It

[1] Epstein: Prager med. Wochenschr., 1880, 45, 450.
[2] Epstein: Prager med. Wochenschr., 1881, 33–34.
[3] Epstein: Jahr. f. Kinderh., 1887, xxvii, 113.
[4] Czerny: Prager med. Wochenschr., 1893, 495, u. 510.
[5] Wohlmann: Jahr. f. Kinderh., 1891, xxxii, 297.
[6] Tobler and Bogen: Monat. f. Kinderh., 1908–1909, vii, 12.
[7] Leven and Barret: Presse Medicale, 1906, 63, 503.

can be said in general on the basis of these observations, that the stomach digestion lasts in the breast-fed baby from one and a half to two hours, and in the artificially-fed baby three hours. Pisek and Lewald believe that a large number of stomachs practically empty themselves within an hour, while A. H. Meyer,[1] and Von Monrad think that it is three and one-half hours before the stomach is emptied. A large meal obviously requires a longer period for digestion than a smaller one, and cow's milk remains longer in the stomach than human milk.[2]

Ladd's[3] extended series of observations on babies, and Cannon's[4] on animals, have done much to increase our knowledge of this complicated subject. The infant's stomach, as compared with the adult's, shows a "curious lack of peristalsis." Shortly after food is ingested some of it may be discharged into the duodenum, without undergoing stomach digestion. It has been found in animals that carbohydrates leave the stomach the most rapidly of the three food components, a large part of them being discharged within two hours, while proteins are discharged less rapidly, and fat the most slowly. These facts fit in with the economy of the body, since carbohydrates are not digested at all by the gastric juices, and are, therefore, passed along to the small intestine as quickly as possible; whereas the proteins, which are digested by the gastric juices, are retained for this action. The fats, on the other hand, are discharged from the stomach at such a slow rate that there is never any great accumulation of fat in the small intestine, the rate of the discharge from the stomach being approximately the same as that of the departure of fat from the small intestine. The discharge of mixtures of food depends upon the relative proportions of fat, carbohydrate and protein which they contain (Cannon). These findings in animals have been partially confirmed in a few observations on infants. In one instance, however, in which the infant received a food containing no fat, 6.62% sugar, and 3.5% protein, the stomach was not empty at the end of 7½ hours. If, however, a fresh feeding is given before the stomach is empty, the bismuth feeding is frequently pushed out into the small intestine by the second meal. Tobler and Bogen[5] also found that milk mixtures containing much cream pass more

[1] Meyer, A. H.: Bibliothek f. Laeger, 8, R, III, 390–512. Kopenhagen 1902. Ref. im Jahr. f. Kinderh., 1903, u, Folge, lviii, 275.

[2] Tobler and Bogen: Monat. f. Kinderh., 1908–1909, vii, 12.

[3] Ladd: Am. Jour. Dis. Children, 1913, v, 345.

[4] Cannon: The Mechanical Factors of Digestion, London and N. Y., 1911.

[5] Tobler and Bogen: Monatschr. f. Kinderh., 1908–1909, vii, 12.

slowly through the pylorus than those with low percentages of fat.

Gastric Motility.—The motility of the stomach is in inverse proportion to the concentration of the food; in other words, the greater the dilution of the milk, the more rapidly the organ empties itself.[1] In animals, the stomach is found to show signs of motor activity shortly after milk has been swallowed. According to the character of the movements of the gastric wall, two regions may be distinguished. The movements of the left hand, or cardiac part of the stomach, consist of slow, shallow, peristalsic waves, which gently push the food lying next to the gastric wall toward the pylorus. The cardiac part of the stomach acts as a reservoir, where the food lies undisturbed by any movement except such as is necessary to pass the peripheral layer on to the pyloric half. The state of affairs is different in the right half of the stomach. Five to eight minutes after the ingestion of food, deep peristaltic rings advance toward the pylorus and press the gastric contents strongly against the pyloric valve. The valve opens from time to time and allows some of the food to pass into the small intestine.[2, 3] It has thus been shown by Cannon, in his Rœntgen ray work on cats, that the two parts of the stomach have two distinct functions, the left, or cardiac half, acting as a reservoir, in which the food lies practically undisturbed until it is passed on to the right or pyloric portion. Here it is thoroughly mixed under greater pressure, and is finally pushed into the small intestine.

Tobler [4] was able to show, in a boy with a gastric fistula, that the coagulation of casein begins in from two to three minutes and is complete in ten minutes. This process is of great importance, since it is found that the fluid portion, containing the milk sugar in solution, is rapidly expelled from the stomach, while the curd, containing casein with fat entangled in its meshes, remains behind for further digestion.[5] Nature thus provides that too much fat is not set free at one time. The fluid gastric contents begin to pass through the pylorus before the infant has stopped nursing.

The cardiac end of the stomach has a very delicate mechanism of its own by means of which it is at times closed, at others open. In cats the cardia is alkaline. As soon as it becomes acid, the car-

1 Clark: Am. Jour. Med. Sciences, May and June, 1909, 674, 872.
2 Cannon: Am. Jour. Phys., 1898, I, 359.
3 Cannon: Am. Jour. Med. Sciences, 1906, cxxxi, 563.
4 Tobler: Verhandl. d. Gesell., Kinderh., 1906, xxiii, 144.
5 Moritz: Zeitschr. Biol., 1901, xlii, 565.

diac orifice closes and remains so until the neighboring food components become alkaline.[1] The pyloric valve acts in a manner directly opposed to that at the cardia. When the material in the antrum pylori is acid, the valve opens and vice versa.[2]

On the duodenal side of the pyloric valve an alkaline reaction allows the valve to open and an acid reaction causes it to close. Cowie and Lyon [3] found that the opening and closing reflex of the pyloric valve could also be demonstrated in infants. When the food was made acid the duodenal closing reflex is sustained and the evacuation of food from the stomach is consequently delayed, even if the stomach contents are acid. Strongly alkaline food, on the other hand, causes the pyloric opening reflex to be delayed and as a result the food is retained longer in the stomach. Free hydrochloric acid is not necessary for pyloric opening in the infant, and it may provoke prolonged closing from the duodenal reflex.

Solid particles of food may be pushed against the pylorus without opening the valve [4] and it is supposed that the curd of milk will have considerable mechanical influence on the opening and closing of the pylorus, while fat, whey, and lactose have little or no mechanical action. Tobler [4] has also shown that the rapid inflation of a balloon in the duodenum checks the passage of food from the stomach. Cannon [5] believes that the evidence is opposed to the conception that mechanical agencies, acting either in the stomach or in the intestine, play an important part in controlling the normal gastric evacuation.

Secretion of the Stomach.—Pepsin has been found in the stomachs of fetuses born at four and at six months,[6, 7] and is always present in the stomachs of babies born at term.[8] Breast-fed babies secrete less pepsin than artificially-fed babies. Rennin is practically always present at birth.[9] Heubner [10] found lactic acid in babies' stomachs, but Sotow [11] and Hamburger and Sperk were

[1] Cannon: Am. Jour. Phys., 1908, 1909, xxiii, 105.

[2] Cannon: Am. Jour. Med. Sciences, 1906, cxxxi, 563.

[3] Cowie and Lyon: Am. Jour. Dis. Children, 1911, ii, 252.

[4] Tobler: Zeitschr. Physiol. Chem., 1905, xlv, 185.

[5] Cannon: The Mechanical Factors of Digestion, London and New York, 1911.

[6] Langendorff: Arch. f. Anat. u. Physiol., 1879.

[7] Huppert: Wiener Sitsungsberichte, 81, Abt. 3.

[8] Zweifel: Untersuchungen über den Verdauungsapparat der Neugeborenen, Berlin, 1874.

[9] Hamburger and Sperk: Jahr. f. Kinderh., Neue Folge, 1905, lxii, 495.

[10] Heubner: Jahr. f. Kinderh., 1891, xxxii, 27.

[11] Sotow: Diss. St. Petersburg, 1895.

unable to confirm these findings. A. H. Meyer explained these conflicting results when he found that lactic acid appeared within two hours after the feeding of mixtures of cows' milk, and that it never appeared after a test meal of tea, or a "water meal." This makes it practically certain that the lactic acid found in the stomach is not the result of gastric secretion, but of the action of the stomach juices or of bacteria on the food.

Engel [1] studied an infant of four weeks with a fistula in the upper duodenum, in which the connection between the stomach and duodenum was apparently cut off. The infant received nothing by mouth. Engel was able to collect from 100 to 200 cubic centimeters of gastric secretion per day by means of a small rubber tube passed through the mouth, and found in this pepsin, rennin, and free hydrochloric acid. He was unable to demonstrate a fat-splitting ferment or lactic acid. There is a difference of opinion concerning the presence of fat-splitting ferments in the stomach of infants from birth onward. Sedgwick [2] removed the stomach contents and found that they were able to split fat. This property is present at birth in rabbits and at a very early age in babies (in one case at two weeks). Hess [3] found lipase in the stomach of the unfed new-born infant. As much as 25% of the fat in the food can be split by the gastric juices, although it is believed that under normal conditions less than this is split. In infants between one and four months old, the lipase content of the stomach increases with the age of the infant.[4]

Kramsztyk [5] found trypsin in a small proportion of the infants to whom oil test meals had been given. It is believed that this trypsin has its origin in the pancreas and is regurgitated into the stomach. (Ibrahim.)

Practically all of the factors present in the adult digestion are present in babies, but in a weaker form.

Free Hydrochloric Acid.—Free hydrochloric acid is never found in the stomachs of some healthy breast-fed infants [6] while in others it is found regularly.[7] Hess [8] found it regularly in the

[1] Engel: Archiv. f. Kinderh., 1909, xlix, 16.

[2] Sedgwick: Jahr. f. Kinderh., 1906, lxiv, 194; also, Arch. Ped., 1906.

[3] Hess: Am. Jour. Dis. Children, 1913, vi, 264.

[4] Hahn: Am. Jour. Dis. Children, 1914, vii, 305.

[5] Kramsztyk: Przeglad Pedyatryczny, 1909, i, 209.

[6] Heiman: Arch. Ped., 1910, xxvii, 570; Labbe: Rev. mens. des mal de l'enfance, 1897, xv, 401.

[7] Cassel: Arch. f. Kinderh., 1890, xii, 175; Wohlmann: Jahrb. f. Kinderh., 1891, xxxii, 297.

[8] Hess: *loc. cit.*

stomachs of new-born infants even before food was given. Whether free hydrochloric acid is found or not in a given instance seems to depend upon the technique of the investigator. It may be said, in general, that the longer after a meal the stomach contents are tested, the more frequently hydrochloric acid is found. It is obvious that when a baby receives a food containing much casein, free hydrochloric acid will appear much later than when it receives a food which contains but little casein or other material with which hydrochloric acid can combine.

Dundin [1] found that the reaction of the gastric mucous membrane of the fetus was always neutral up to the sixth month, after which it was acid. He was unable, however, to demonstrate free hydrochloric acid in any fetus. Hamburger and Sperk [2] found small amounts in the stomachs of new-born babies from the third to the eighth day. The amount increases with the age of the baby (A. H. Meyer). About three times as much becomes "combined acid" on artificial feeding as on breast feeding. The acidity immediately after a meal is nil, but steadily increases during digestion, the rapidity of the increase varying directly with the age of the child. Free hydrochloric acid appears in a few minutes after a feeding of barley water. It does not appear, however, for an hour or more after a feeding of milk, the delay being due to the power of casein to absorb and combine with acid. Free acid appears later in disease than in health.[3] It is interesting to note that the breaking down of sugar into lactic acid is retarded by the presence of from .01% to .02% of hydrochloric acid and prevented by .07% to .08%. The power of casein to delay the appearance of free hydrochloric acid explains the fact that lactic acid is frequently present in the stomachs of babies fed on cows' milk.[4, 5, 6]

The recent studies of Hahn [7] of the hydrogen-ion concentration of the gastric contents have added light from another point of view. He found that the acidity of the stomach juices, when studied in this manner, was strikingly constant being $(H) = 1.0 \times 10^{-5}$. This is in striking contrast to the figures given above of the titrable acidity, and is considered to be the normal acidity of the stomach

[1] Dundin: quoted by Gundobin, Die Besonderheiten des Kindesalter, Berlin, 1912, 269.

[2] Hamburger and Sperk: Jahrb. f. Kinderh., 1905, lxii, 495.

[3] Clark: Am. Jour. Med. Sciences, May and June, 1909, 672, 872.

[4] Sieber: Nad. Jour. f. prakt. Chemie, 1879, xix, 433.

[5] Cohn, F. O.: Zeitschr. f. Phys. Chem., 1890, xiv, 75.

[6] Hirschfeld: Pfluger Arch., 1890, xlvii, 510.

[7] Hahn: Am. Jour. Dis. Children, 1914, vii, 305.

contents at the height of digestion, when the food is either one-third or two-thirds milk. He believes that this is the optimum acidity for the action of rennet and gastric lipase and that it inhibits the action of pepsin.

Our conception of the therapeutic action of alkalies in modifying gastric digestion has recently been changed. It has been claimed by Southworth [1] and others, on the basis of the work of Van Slyke and Hart, that lime water and sodium bicarbonate neutralize the hydrochloric acid secreted in the stomach, and thus delay the coagulation of milk by rennin. As the result of this delay a portion of the milk is allowed to pass into the duodenum before coagulation takes place. The amount of alkali given should be calculated in relation to the amount of milk and cream used in the mixture and not to the total quantity of the mixture, because the milk and cream alone contain casein and it is the casein which is acted upon by the rennin. This seems to be the most reasonable view to take at present. Clark [2] claims, however, that lime water does not reduce the acidity of the gastric contents, and that the neutralization of a portion of the acid is overcome by an increased stimulation of the gastric glands to form hydrochloric acid. The amount of acid available for digestion may thus be even increased. These findings presumably apply also to bicarbonate of soda. The evidence in relation to this subject is conflicting and it is by no means certain that the present conception of the action of alkalies will not be greatly modified by future investigations. The action of sodium citrate has recently been shown by Bosworth (see chapter on Chemistry of Cow's Milk) to be dependent in large part on reactions that occur in the milk itself. It changes the compound known as calcium caseinate into sodium caseinate. Sodium caseinate is changed by rennin to sodium paracaseinate, which is soluble, while calcium paracaseinate, which is formed from calcium caseinate, is insoluble. Coagulation by rennin is thus prevented. To what extent sodium citrate may also combine with the hydrochloric acid of the stomach to form sodium citrate and thus reduce the amount of "available hydrochloric acid," is unknown.

Rennin: (Chymosin).—The rennin ferment has been found in the stomach on the first day of life.[3] It causes the coagulation of milk. It is in the form of a pro-ferment in the gastric mucous membrane, which is inactive until it has come into contact

[1] Southworth: Arch. of Pediatrics, Feb., 1905, p. 131.
[2] Clark: *loc. cit.*
[3] Szydlowski: Jahrb. f. Kinderh., 1892, xxxiv, 411.

with hydrochloric acid.[1] According to Hahn[2] it works best with a hydrogen-ion concentration $(H) = 1.0 \times 10^{-5}$. Some writers,[3, 4] believe that rennin and pepsin are identical, because it has been impossible to separate the two enzymes by obtaining specific antibodies for them. There is not sufficient evidence available to settle this question.

Pepsin.—Pepsin has been extracted from the gastric mucous membrane of a four months' old fetus[5] and is usually present at all ages in both health and disease.[6] Healthy breast-fed infants seem to produce less than healthy artificially-fed infants of the same age. The amount increases from birth until the end of the third month of life, after which it remains constant. Older babies of less than the normal weight produce the amount of pepsin which corresponds to their ages.[7] The stomachs of babies with severe chronic disturbances of nutrition frequently contain no pepsin. When these babies improve in health and gain in weight, their stomachs again contain pepsin. The stomach juice of normal infants is capable of transforming protein into peptone.[8, 9] Pepsin is present in the gastric glands as pepsinogen (Glassner), which is converted by hydrochloric acid into pepsin. An hydrochloric acid extract of the gastric mucous membrane quickly loses its power of peptonization when the acid is neutralized with soda.

Absorption in the Stomach.—Most of the direct experiments on gastric absorption have been done on animals and indirect methods have to be depended upon in babies. Pfannenstill[10] found that iodine appeared in the urine of healthy breast-fed babies in from fifteen to twenty-five minutes after it was given by mouth. These results have been confirmed by other observers. Gundobin[11] found that the absorptive power of the stomach (for KI) was diminished in disease in direct proportion to the severity of the disease. For example, in "dyspepsia" potassium iodide was absorbed on the average in 17.1 minutes, in "gastro-enteritis" in 24½ minutes, and in "cholera infantum" in 34.9 minutes. According to Can-

[1] Glaessner: Beitr. zur chem. Physiol. u. Path., 1902, i, 24.
[2] Hahn: Am. Jour. Diseases of Children, 1914, vii, 305.
[3] Pawlow and Parastschuk: Zeitschr. f. Physiol. Chemie, 1904, xlii, 415.
[4] Blum and Boehme: Hofm. Beitr. z. chem. Physiol. u. Path., 1907, ix, 74.
[5] Langendorff: Arch. f. Anat. u. Physiol., 1879, 95.
[6] Clark: *loc. cit.*
[7] Rosenstern: Berliner klin. Woch., 1908, xlv, 542.
[8] Ramsey: Arch. Ped., May, 1909, 341.
[9] Langstein: Jahr. f. Kinderh., 1906, Neue Folge, lxiv, 139.
[10] Pfannenstill: Nord. med. Archiv., 1892, Neue Folge, ii, Heft 10.
[11] Gundobin: Die Besonderheiten des Kindesalters, Berlin, 1912, 272.

non[1] absorption is an associated function of the churning action in the vestibule of the stomach. "Although water is not absorbed in the stomach, glucose in concentrated solution, and proteins which have been exposed to gastric digestion, may be absorbed in considerable amount (V. Mering and Tobler). The mucosa of the vestibule has fewer glands than the mucosa of the cardiac end, where they are placed in very close order. The absorption that occurs in the stomach probably takes place, therefore, in the vestibule, for there the epithelial surface is most favorable to the process. There also gastric digestion is most advanced, and the food in consequence is most ready for passage through the mucosa. Furthermore, the mechanical conditions in the vestibule are most favorable to absorption because the digested food is repeatedly brought into very close contact with the mucous lining."

PANCREAS

The weight of the pancreas increases in general parallel with the body weight. Taking average figures, the increase of weight in intra-uterine life is relatively rapid, so that it is forty times larger at birth than it is at the third month of fetal life. After birth it doubles in weight in from three to four months, at the same time increasing its functional activity proportionately. The increase in weight from this time on is slower.

The table of Hartge[2] on page 14 (Table 5) gives the weights and measurements of the pancreas:

The pancreatic secretions contain three digestive ferments, namely, trypsin which splits up protein, amylopsin which changes starch into sugar, and steapsin which splits neutral fat into fatty acids and glycerin. All these ferments are probably present in the pancreas of the human fetus from the third month of fetal life onward. At birth the amount of trypsin and steapsin is less than in the adult, and amylopsin is always found during the first week of life and increases in amount with the age of the infant.[3, 4, 5, 6] In chronic diseases such as congenital syphilis and "enterocolitis" there may be an interstitial pancreatitis with a corresponding

[1] Cannon: The Mechanical Factors of Digestion, New York and London, 1911, 68.

[2] Hartge: The Pancreas of the Fœtus and Newborn: Diss. St. Petersburg, 1900 (Russian), quoted by Gundobin.

[3] Hess: Am. Jour. Dis. Children, 1912, ii, 205, Summary of Literature.

[4] Moro: Jahrb. f. Kinderh., 1898, xlvii, 342.

[5] Ibrahim and Gross: Ref. Deut. med. Wochenschr. Vereinsbeilage, 1908, xxv, 1128.

[6] Hartge: *loc. cit.*

TABLE 5

Age	*Number of cases*	*Wt. in grammes*	*Average length in cm.*	*Width in cm.*	*Thickness in cm.*
3 mos. fetus	1	0.07	1.1	0.4 -0.2	
4 " "	2	0.145	1.65	0.75-0.27	0.33-0.17
5 " "	3	0.38	3.2	0.8 -0.5	0.34-0.21
6 " "	6	0.38	3.2	0.8 -0.48	0.38-0.25
7 " "	2	0.76	4.35	1.0 -0.63	0.4 -0.25
8 " "	2	1.18	4.32	1.2 -0.7	0.6 -0.35
9 " "	4	1.63	5.7	1.5 -0.85	0.58-0.35
1-2 months	3	2.61	6.93	1.6 -0.9	0.66-0.56
2-3 "	3	2.64	7.54	1.6 -0.9	0.65-0.5
3-4 "	3	4.93	7.46	2.1 -1.5	0.8 -0.57
4-5 "	3	5.4	7.5	2.25-1.5	0.85-0.8
5-6 "	3	5.28	7.0	1.75-1.25	0.95-0.65
6-9 "	3	7.37	8.2	2.0 -1.6	1.0 -0.65
9-12 "	3	8.67	9.5	2.0 -1.2	0.9 -0.45

weakening of the pancreatic ferments (Gundobin). Hess [1] has shown that lipase (steapsin) may be deficient in acute intestinal indigestion while the two other pancreatic ferments are present in considerable amounts.

The secretin of the intestinal mucous membrane stimulates the production of the pancreatic ferments. Bayliss and Starling [2] showed that when inorganic or organic acids were discharged from the stomach into the duodenum secretin was set free. When secretin is carried by the blood to the pancreas it starts the pancreatic secretion. Secretin has been found in the fetus and in many new-born babies. The peptic ferment, trypsin, is present in the pancreas as the pro-ferment trypsinogen. Many fetuses have trypsinogen, but no trypsin. The secretion of enterokinase is called forth by the pancreatic juice and has been demonstrated in new-born and premature babies by Ibrahim. The pancreatic ferments, with the added action of erepsin, carry the digestion of proteins from albumoses and peptones into amino acids.

The fat-splitting ferment, called lipase or steapsin, is active in acid, alkali, or neutral surroundings. This ferment is present in the pancreatic juice in part as a pro-enzyme, which is changed by the bile into steapsin. The bile in this way increases the fat-splitting power of the pancreatic ferments [3] and facilitates emulsion.

[1] Hess: Am. Jour. Dis. Children, 1913, v, 268.
[2] Bayliss and Starling: Jour. Physiol., 1902, xxviii, 325-53, 1903, 174.
[3] Furth and Schutz: Hofm. Beit. z. chem. Physiol. u. Path., 1907, ix, 28.

There is no work upon the sugar-splitting ferments in babies other than that of Ibrahim,[1] Miura,[2] neither of whom are able to find any in the new-born.

LIVER

The weight of the liver post mortem depends upon whether or not it is full of blood. When the former weight is taken, it is known as the "physiological weight," and the latter as the "post mortem weight." The physiological weight is obtained by filling the liver to its maximum with water, after it has been removed from the body.

The following table of Kowalski's [3] gives the weights of the livers of fifty normal infants:

TABLE 6

Age	*No. of cases*	*Total wt. of liver in grammes*	*Body weight in grammes*
5 mos. fetus	1	39	650
7 " "	1	70	1,320
8½ " "	1	110	2,000
9 " " female	1	100	1,900
9 " " male	2	92	2,000
New-born	3	130	3,000
1–7 days	4	133.5	3,150
2–3 mos.	6	187.5	4,075
3–4 "	4	259	4,350
4–5 "	2	248	5,900
8–10 "	2	320	7,000
15 "	2	325	10,000

The weight of the liver in comparison with that of the body is 4.33% in the new-born and 2.85% in the adult. The function of the liver is to manufacture bile and to change carbohydrates, proteins and fats into glycogen.[4] Its cells also play an important part in the formation of urea.

Bile.—The composition of bile, according to Geptner,[5] is as follows:

[1] Ibrahim: Verhandl. d. Gesell. für Kinderh. Köln., 1908, 21.

[2] Miura: Zeitschr. f. Biologie. 32 Neue Folge, 1895, xiv, 266.

[3] Kowalski: Die Leber des Kindes. Diss. St. Petersburg, 1900 (Russian), quoted by Gundobin.

[4] Kowalski: *loc. cit.*

[5] Geptner: Die Chemische Zusammensetzung der Galle des Kindes. Diss. St. Petersburg, 1900 (Russian), quoted by Gundobin.

TABLE 7

Age	*Amount*	*Composition of the bile*							
		Water	Solids	Mucin	Bile salts	Sodium glyco-cholic acid	Sodium tauro-cholic acid	Choles-terin, Fat, Le-cithin	Mineral salts
Infants	Per cent	93.54	6.46	1.56	2.35	1.40	0.90	1.86	0.53
	of 100 parts of dry substance		100	25.23	35.09	21.22	13.11	28.44	8.08
12–18 months	Per cent	91.87	8.13	1.54	3.32	2.21	1.06	2.26	0.86
	of 100 parts of dry substance		100	19.13	40.88	27.11	13.16	27.18	10.89
Adults	Per cent	87.61	12.37	1 98	6.38	3.49	1.57	1.99	0.82
	of 100 parts of dry substance		100	16.0	51.57	28.21	12.69	16.09	6.62

The bile salts are of importance in activating the pancreatic juices and in acting with them in splitting the fat. The liver, besides secreting the bile, acts as a protection against bacterial and other poisons.[1]

INTESTINES

The length of the intestinal tract increases fairly regularly with the age of the infant.

The table on page 17 is the result of measurements by Debele: [2]

Small Intestine.—The juices of the small intestine contain invertin (Ibrahim), both in the fetus and in the new-born. Several writers,[3, 4, 5] have demonstrated erepsin in the fetus and other ferments have been identified by other writers.

Carbohydrates are split into monosaccharides in the small intestines, where they are absorbed. The specific ferments, invertin, lactase, and maltase convert the corresponding sugars into mono-

[1] Uffenheimer: Ergebnisse d. inn. Med. et Kinderh., 1908, No. 2, 271.

[2] Debele: Die Lange des Darmkanals im Kindesalter. Diss. St. Petersburg, 1900 (Russian), quoted by Gundobin.

[3] Langstein and Soldin: Jahrb. f. Kinderh., 1908, Neue Folge, lxvii, 9.

[4] Jaeggy: Zentralblatt f. Gynäk., 1907, No. 35, 1060.

[5] Foa: Münch. med. Wochenschr., 1907, 2201.

TABLE 8

Age	*Number of cases*	*Length of trunk from the 7th cervical vertebra to the coccyx in cm.*	*Length of the small intestine in cm.*	*Length of the large intestine in cm.*
1 month	4	21.5	296.4	63.3
1–2 mos.	6	21.1	319.1	65.1
2–3 "	14	22.2	358.1	70.6
3–4 "	5	23.1	379.4	71.2
4–5 "	4	25.5	383.4	72.3
5–6 "	5	25.1	380.3	69.2
7–9 "	2	27.0	412.4	80.5
6–12 "	6	27.0	419.8	83.9
Average	46	23.5	365.3	71.6

saccharides and are either present in the digestive juices or in the mucous membrane. Food stays a relatively short time in the small intestine, but during that time is mixed with and acted upon by the digestive juices so that it is ready for absorption before it reaches the large intestine.

There is nothing definitely known about the secretions of the large intestine.

CHAPTER II

THE DIGESTION AND METABOLISM OF FAT[1]

The fat in the infant's food is principally in the form of neutral fat. Saliva has no action upon it, and, although saponification begins in the stomach, it probably is not carried on to a point which influences to any degree the future digestion of the fat. The action of the fat-splitting ferment of the stomach is eventually stopped entirely by the acid reaction of the stomach contents. The action of the gastric secretions is of importance indirectly, because when milk is coagulated by rennin, most of the fat is ensnared in the meshes of the casein curds, and the casein coating must be first digested before the digestive juices can reach the fat. There is, therefore, very little opportunity for the absorption of fat in the stomach. This ensnaring of the fat by the casein may be of physiological importance in preventing the liberation of too large an amount of fat in the intestinal canal at one time.

Fat has a definite influence on the emptying time of the stomach, large amounts tending to delay it.[2] Large amounts of fat in the food are, according to Tobler [3] of etiological significance in the pathogenesis of pyloric spasm. He found in the stomach of one infant more fat than had been given to it during the previous twenty-four hours. He also calculated that one litre of milk would cause one and a half litres of digestive juices to be secreted.

The real digestion of fat commences when it reaches the small intestines, where it undergoes a physical change. The fat is first of all subdivided by the alkaline salts of the bile, and of the pancreatic and intestinal juices. Fatty acids, which are formed as the result of the action of the fat-splitting ferments, react with the alkaline carbonates present to form soaps. The soaps which result make the fat particles still smaller and form an emulsion.

Absorption.—There is considerable evidence to show that neutral fat (unsplit fat), is not absorbed as such into the intes-

[1] Tobler and Bessau: Allegemeine Pathologisehe Physiologie der Ernährung und des Stoffwechsels im Kindesalter, Wiesbaden, 1914, has been consulted and quoted freely in this section.

[2] Tobler and Bogen: Monatsschr. f. Kinderh., vii, 12.

[3] Tobler: Verhandl. d. Gesellschaft f. Kinderh., 1907, 411.

tinal wall: for example, hydrous wool fat and paraffin, which may be made into emulsions but cannot be split, are not absorbed.[1] It has also been shown by animal experimentation that the amount of fat in the chyme is directly proportional to the amount of fat which has been split.[2] It is also taught by some that fat is absorbed both in the form of an emulsion and in the form of water-soluble soaps, neither view excluding the other.

Bloor [3] found that substances similar to food fat in that they emulsified well, were soluble in fat solvents and were liquid at temperatures below that of the body, but could not be converted into a water soluble form, and were not absorbed at all in the intestinal canal. He concluded that the slow passage of fats from the stomach, the abundant provisions for hydrolysis and for the absorption of fat-like substances which cannot be changed to a water soluble form, make it extremely probable that saponification is a necessary preliminary to absorption. The significance of the mechanism involved is little understood, but one of its uses would appear to be to exclude undesirable fat-like substances which would otherwise be carried in with the fats.

Kastle and Loevenhart [4] demonstrated the almost universal presence of lipase in the tissues, and showed that this ferment could reverse its action. That is to say, it can synthesize or change soaps back into neutral fats as well as split neutral fats and form soaps. It is, therefore, possible that the soaps, which have been formed during the digestion, may be changed back during their passage through the intestinal epithelium by the reversible action of lipase into neutral fat, because neutral fat is found almost exclusively in the lymph stream. Whitehead's [5] experiments on cats seem to strengthen this statement, because he found that butter-fat stained with Sudan III lost the stain during absorption (soaps will not stain with Sudan III); Sudan-staining fat was seen in the lumen of the intestine; none was seen in the intestinal epithelium and a Sudan-staining fat was again found in the lacteals of the villi.

Noll [6] and Wilson [7] conclude from their studies with animals that the epithelium of the intestinal mucous membrane plays a part in the absorption of fat. The emulsified fat is taken up into the

[1] Connstein, W.: Arch. f. Anat. u. Physiol., 1899, 30; Henriques and Hansen: Zentralblt. f. Physiol., 1900, xiv, 313.

[2] Levites: Ztschr. f. physiol. Chem., xlix, 273; liii, 349.

[3] Bloor: Jour. Biol. Chem., xv, 105, and Jour. Biol. Chem., 1914, xvi, 517.

[4] Kastle and Loevenhart: Am. Chem. Jour., 1900, xxiv, 491.

[5] Whitehead: Am. Jour. Physiol., 1909, xxiv, 294.

[6] Noll: Arch. ges. Physiol., cxxxvi, 208.

[7] Wilson: Trans. Canadian Inst. Sept., 1906, viii, 241.

striated cells bordering the villi. These cells contain a considerable amount of fat before the fat can be detected in the lacteals. A stage is then reached in which the fat content of the mucosa further increases and at the same time removal through the lacteals sets in. The fat is then found in the lacteals until all the fat has been removed from the epithelial cells. There is hardly any evidence to show that the fat can be carried from the epithelial cells to the lacteals by leucocytes. Samelson [1] has found a fat-splitting enzyme in the blood of infants. It is probable that most of the fat which is absorbed goes into the thoracic duct and from there is poured into the blood stream. The fate of a not inconsiderable portion of the absorbed fat has not yet, however, been determined.

When the fat has entered the blood stream it can be demonstrated by the ultra microscope. When fat is present in the blood after food has been taken, the condition is called digestion lipemia. It commences two to three hours after meals and disappears after seven to eight hours.[2] The height of the curve is dependent on the amount of fat in the food, and also on the age and condition of the infant. The absorption of fat is extraordinarily good in health in babies fed on cow's milk as well as in those fed on human milk. It is usually over 90% and may be as high as 98% of the fat ingested; [3] 8% to 11% of the ingested fat is absorbed in the upper part of the small intestine [4] and the absorption of fat is nearly complete at the ileocecal valve.[4] The large intestine is capable of absorbing fat in large amounts under special favorable conditions,[5] but under ordinary circumstances absorption here is probably very slight.

The results of estimations of the amount of fat in the stools of babies in starvation and in health make it probable that the greater part of the fecal fat comes from the food and not from the intestinal secretions.[6] It is evident, therefore, that the study of the fat in the stools with the microscope will give valuable information about the digestion. It is necessary first to know how much

[1] Samelson: Zeitschr. f. Kinderh., 1912, iv, 205.

[2] Neumann: Wien, klin. Wochenschr., 1907, 851; Schelble: München med. Wochenschr., 1908, No. 10, p. 492; Bahrdt: Breslauer Tagung der Freien Vereinigung für wissenschaftliche Pädiatrie, 1908, Monatschr. f. Kinderh., vii, 106.

[3] Czerny and Keller: "Des Kindes Ernährung, Ernährungstorüngen und Ernährungs therapie," Leipzig u. Wien, 1906, I, 263; Freund: Ergebn. d. inn. Med. u. Kinderh., 1909, iii, 139.

[4] Levites: *loc. cit.*

[5] Hamburger, H. J.: Engelmann's Arch., 1900, 433.

[6] Czerny and Keller: *loc. cit.*

fat may normally be found in a stool. There is a comparatively large amount of fat present in the first days of life, and this amount gradually becomes less as the babies grow older,[1] decreasing from 50% of the dried stools to between 14 and 25%. There is so much fat passed in the stools during the early weeks that it is practically impossible to ascertain by simple microscopic examination whether there is an excess or not. In later infancy less fat is present and, therefore, microscopic examinations are of more value. In normal and in many pathologic conditions the greater part of the fat, 75% or more, is split by the digestive juices and bacteria into fatty acids and soaps.

METABOLISM

Methods.—Most of the earlier figures of the metabolism of fat were obtained by the Rosenfeld extraction method,[2] or one of its modifications. Later Kumagawa and Suto [3] criticised these methods and devised a saponification method which goes under their name. These two methods are the ones most commonly used on the continent. The Folin-Wentworth method [4] (extraction) is now used in America almost to the exclusion of the other two methods. Gephart and Csonka [5] have recently shown the presence of errors in all of the above methods and have described a method by which they have endeavored to overcome these errors. Up to date there are no metabolism figures in infancy which were obtained by this method. When the methods are studied, it becomes obvious that figures obtained by one method cannot fairly be compared with those obtained by another method, because they probably do not represent the same things. It is obvious also that slight differences in figures are of no significance and that only the most striking differences are of practical importance. Unfortunately, the clinical status of the infant is not sufficiently controlled and recorded in most instances and the possibilities of error, both from errors in chemical technique, and in clinical observation, are numerous. Despite these facts, it seems wise to summarize what we think we know about the digestion and absorption of fat in health and disease.

Fat Excretion on Fat-free Food.—A careful analysis of the figures that are at present available shows that even when the

[1] Talbot, F. B.: Boston Med. and Surg. Jour., 1909, vol. clx, No. 1, 13.
[2] Rosenfeld: Centralb. f. inn. Med., 1900, xxi, 833.
[3] Kumagawa and Suto: Biochem. Zeitschr., 1908, viii, 212.
[4] Folin and Wentworth: Jour. Biol. Chem., June, 1909–10, vii, 421.
[5] Gephart and Csonka: Jour. Biol. Chem., Dec., 1914.

quantity of fat in the food is very minute, an ether soluble substance, which is recorded by investigators as fat, is found in the stools. In most instances in infants the amount of this substance is smaller than the amount of fat in the food, and if it is fat it might very well originate in the food.[1] On the other hand, since fasting adults have had small quantities of fat in the stools, it is argued that this fat must come from the body. The amount of fat in question is so small that the discussion is of more theoretical than practical importance.

Fat Absorption in Health.—It is generally agreed that the fat absorption of healthy infants is very high both in the breast-fed and in the artificially fed. Uffelmann [2] found that a breast-fed infant absorbed approximately 97.8% of the fat ingested. Shaw and Gilday [3] found the absorption 96%, while Nobècourt and Merklen [4] found the absorption of fat respectively 98.3, 99.7, 98.27, 98.23, and 98.62% in five healthy breast-fed infants. Further figures are given by Czerny and Kellar.[5]

The absorption of fat in normal artificially-fed babies is also extraordinarily good and, according to Freund, it may remain absolutely normal even under abnormal conditions of nutrition. He records instances with "soap stools" in which the fat absorption reached as high as 97% of the intake (see Czerny and Kellar,[5] and Freund).[6] Freund gives 91.86% to 98.98% as the figures for the absorption of fat for healthy, breast-fed infants. The figures are somewhat lower in the babies he calls "apparently normal," but analyses of these figures show that these babies are considerably under the average weight for their age and can, therefore, not be considered "average normal." Nevertheless many of these infants show a very good absorption of fat.

The significance of fatty acids and soaps is as yet unknown. Freund [7] has shown that an acid dyspeptic stool can be changed in many instances to a formed "soap stool" by a relative increase in the amount of casein, while an alkaline soap stool can be changed into an acid stool by a relative increase in the amount of carbohydrates. Coincident with the change from an acid to an alkaline stool there is a change of the intestinal flora; the acid-forming

[1] See expts. of Aschenheim (Kumagawa and Suto method), Jahrb. f. Kinderh., 1913, lxxvii, 505.

[2] Uffelmann: quoted by Tobler and Bessau, *loc. cit.*

[3] Shaw and Gilday: Brit. Med. Jour., 1906, ii, 932.

[4] Nobècourt and Merklen: Rev. mens des Mal. de L'enfance, 1904, xxii, 337.

[5] Czerny and Kellar: *loc. cit.*

[6] Freund: Ergeb. d. inn. Med. u. Kinderh., 1909, iii, 158–159.

[7] Freund: *loc. cit.*

bacteria which previously predominated are replaced by the putrefactive group of bacteria. When an alkaline stool is made acid the reverse takes place. Bahrdt [1] has recently shown that babies passing "soap stools" have diminished powers of absorption and that they lose more fat than was formerly taught. He found the absorption of fat (Kumagawa and Suto method) as follows:

TABLE 9

Name of baby	*Age, months*	*Weight, gm.*	*Fat absorbed, per cent*	*Character of stools*
Schröder, 7 days.....	9	7470	82.4	Soap stools
Schuler, 7 days	2	3945	83.2	Mostly soap stools
Weiss, Ia, 5 days.....	9/10	3750	81.9	Soap stools
Weiss, Ib...........	9/10	3750	86.0	Soap stools
Weiss II, 8 days (Breast and skim milk)	10	3900	93.0	Normal stools

The fat absorption in these babies with soap stools is, therefore, considerably less than that of normal infants. There is, however, not such a loss of fat as in diarrhea.

It is very difficult to determine in the cases that have been previously investigated how much their powers of digestion had been injured by previous poor feeding or disease. Conclusions as to the effect of the food on sick babies, on this account, must be very conservative. There seems to be little doubt, however, that increased peristalsis results in an increased loss of fat in the stools. Certain phases of this question will be considered in more detail later. Increased loss of fat in the stools may occur in any diarrhea, whether it be due for example, to an acute infection, or to chilling, or to an excess of sugar in the food. Birk's observations on Groeger III, during a period in which the temperature was elevated and he was passing frequent thin stools, showed an absorption of only 79%. Courtney [2] says that the lowest absorption in her cases, Janes 52.3% and Stoker 34.2%, was the result of increased peristalsis and diarrhea. Usuki [3] found that when large amounts of malt extract were added to the food of an infant with alkaline stools the loss of fat in the stools increased from 10% to 15%. The same results were recorded for lactose by Talbot and Hill,[4] who found in their

[1] Bahrdt, H.: Jahrb. f. Kinderh., 1910, lxxi, 249.
[2] Courtney: Am. Jour. Dis. Children, 1911, i, 321.
[3] Usuki: Jahrb. f. Kinderh., 1910, lxxii, 18.
[4] Talbot and Hill: Am. Jour. Dis. Children, 1914, viii, 218.

case that the absorption of fat while the digestion was good was 90% and that during a "sugar diarrhea" it dropped to 75%.

The percentage of fat in the dried stool is higher in paraenteral febrile infections than in health. Uffelmann [1] found, for example, that in an eight months' old infant with acute bronchitis and fever the fat excretion in the stools was as follows:

TABLE 10

	Fat
4th day	40.7% of dried stool
7th day	37.8% of dried stool
9th day	25.0% of dried stool
13th day	15.2% of dried stool

Fat Diarrhea.—Demme [2] and Biedert [3] described a condition which they called a fat diarrhea which was characterized by frequent, acid, diarrheal stools. Tobler thinks that, on account of their acidity, these stools are not characteristic of a primary fat indigestion, but that they may be secondary to some other form of indigestion which causes rapid peristalsis. He cites, as evidence in favor of this point of view, the fact that such a diarrhea will stop when the food is changed to "Eiweissmilch," even though the percentage of fat remains the same. It is a fact, nevertheless, that in certain instances, in which very large amounts of fat have been fed to young infants, they have passed three or four stools daily of the yellow color of Indian meal and the consistency of mush. Careful inspection of such stools shows drops of oil on the surface of and intermixed with the stool, while the microscope shows that the stool is composed almost entirely of fat. When the amount of fat is reduced in these cases without any other change in the food, the digestion becomes normal. Such cases are true fat diarrheas.

Whether the fat in the stool is in the form of fatty acids or soaps depends chiefly upon the reaction of the stool, which in its turn depends upon the relation of the food components to each other. Talbot [4] has shown that "soft curds" or fatty curds, when alkaline to litmus paper, are composed principally of soaps and, when acid to litmus paper, principally of fatty acids.

The presence of a large amount of soaps presumably affects the absorption of the various salts. The technical difficulties in deter-

[1] Uffelmann: quoted by Tobler and Bessau, *loc. cit.*

[2] Demme: Jahrb. über die Thätigkeit des Jennerschen Kinderspitals in Berlin, 1874 and 1877; quoted by Hecht, Die Faeces des Säuglings, etc., p. 128.

[3] Biedert: Jahrb. f. Kinderh., 1879, xiv, 336; ibid., 1888, xxviii, 21.

[4] Talbot: Boston Med. and Surg. Jour., 1909, clx, 13.

mining the amount of calcium and other salts in the stools, make nearly all the figures very unreliable.[1] The usual conclusions from metabolism experiments are that in the normal infant, with a normal fat absorption, a high fat intake does not change the mineral composition of the stools, while in chronic malnutrition the output of salts in the feces is considerably raised by increasing the fat in the diet.[2]

Olive oil is considered by some authors to have a beneficial action on the absorption of fat. The metabolism experiments of Courtney [3] and Freund [4] apparently bear out this belief.

Infantile Atrophy.—"Alimentary decomposition" of Finkelstein—"Marasmus"). When the literature of the metabolism of "infantile atrophy" is studied the first questions which arise in the student's mind are what is the clinical picture of "infantile atrophy," and are all the cases reported under that name suffering from the same disease. The summaries of the clinical histories are so meagre that it is impossible to draw any definite conclusions from them and the statement of the investigator as to the clinical status of the given infant has to be accepted. This state of affairs is, of course, unfortunate, but with the present disagreement among authorities as to what the disease really is, it cannot be remedied. With modern improvements in the methods of diagnosis it is possible to separate out chronic tuberculosis and hereditary syphilis as definite clinical entities. Prematurity should also be set aside by itself. This leaves, to be classed as "infantile atrophy," those cases which correspond to Holt's [5] definition, that "infantile atrophy is the extreme form of malnutrition seen in infancy, occurring so far as is known, without constitutional or local organic disease. It is a vice of nutrition only." There must be many stages of the disease if there is such a clinical entity. These facts must be borne in mind in considering the subsequent remarks.

The fat content of the body of an atrophic infant as compared with the normal is very much diminished. Ohlmüller [6] found that the body of an atrophic infant contained only 3% fat as compared to 21% in a normal infant. Steinitz [7] analyzed the bodies

[1] According to Prof. Folin only those figures of the calcium metabolism obtained by McCrudden's methods are of any value.

[2] Freund: Ergeb. d. inn. Med. u. Kinderh., 1909, iii, 139.

[3] Courtney: Am. Jour. Dis. Children, 1911, i, 321.

[4] Freund: Biochem. Zeitschr., 1909, xvi, 453.

[5] Holt: Dis. of Infancy and Childhood, N. Y. and London, 1911, p. 227.

[6] Ohlmüller: Zeitschr. f. Biol. 1882, xviii, 78.

[7] Steinitz: Jahrb. f. Kinderh., 1904, lix, 447.

of three atrophic infants, weighing 3190, 2625 and 1960 grams, and found that the total amount of fat was respectively 63.6, 37.9 and 35.9 grams, or from 1.45 to 1.99% of the total mass, as compared with from 12.3% to 13.1% in the normal.

A fatty liver is occasionally found at post mortem examination, but, according to Holt,—"This lesion is not more frequent in this condition than in infants dying of other diseases." Hayaslei [1] recently showed that in five out of eight cases of "infantile atrophy" the liver contained neither fat nor lipoid substances. In two cases the livers were fatty.

According to many authors [2] the digestive ferments are more or less diminished and weakened in infantile atrophy. This is especially true of the fat-splitting ferment. Hecht believes that there is a connection between the severity of the disturbance and the diminution in the amount of steapsin. Wentworth [3] found that secretin was either diminished or absent in these cases.

The metabolism of fat varies. Freund [4] found that two atrophic infants with "milchnahrschaden" (soft curds) absorbed respectively 90% and 97% of the fat, except in one instance when one absorbed only 81.8%. Bahrdt,[5] on the other hand, found an absorption of only 81.9, 82.4, 83.2, 86.0 and 93%.

L. F. Meyer [6] studied "infantile atrophy" in different stages and with different foods. He found in baby Kajitzki in periods I and II, in which whole milk, diluted one-half, was given, that the absorption of fat was respectively 74.2% and 24.9%. In the first period there was a slight gain in weight, and in the second period a marked loss in weight, with a corresponding loss of fat in the stool. In periods III, IV, and V, the absorption of fat was respectively 51.0, 68.3, and 78.6%, and during the last period there was a gain in weight. Baby Bentler did not show the same loss of fat, but there was a greater retention of fat when human milk was given than when cow's milk was given.

Fife and Veeder [7] studied two cases which they considered to be "infantile atrophy" and found that the fat absorption (Brugsch method for fat) was less than in normal infants. Curiously enough, the per cent. of fat absorbed was larger when large amounts of fat were given than when small amounts were given. They did

[1] Hayaslei: Monatschr. f. Kinderh., 1913, xii, 221.
[2] Tobler and Bessau: *loc. cit.* 130.
[3] Wentworth: Jour. Am. Med. Assoc., 1907, xlix, 204.
[4] Freund: Biochem. Zeitschr., 1909, xvi, 453.
[5] Bahrdt: quoted by Tobler and Bessau, *loc. cit.*
[6] Meyer, L. F.: Jahrb. f. Kinderh., 1910, lxxi, 379.
[7] Fife and Veeder: Am. Jour. Dis. Children, 1911, ii, 19.

not find that the carbohydrates in the food had any influence on the fat absorption, but their evidence in this respect is incomplete.

Wentworth [1] studied the fat metabolism (Folin-Wentworth method), of an atrophic infant and found that its tolerance for the fat in human milk was much greater than for that of cow's milk. His results were confirmed in the case of Kajitzki.[2] He was unable to determine whether this difference in the absorption of the two kinds of fat was due to a difference in the fats themselves or to some other ingredient in the milk.

Hecht [3] and Reuss [4] have reported cases of congenital obliteration of the bile duct with normal pancreas, in which only one-half of the fat was split. In Niemann's case [5] of an infant with advanced biliary cirrhosis and congenital absence of the bile ducts, the nitrogen absorption was from 80% to 93% and the fat absorption from 28% to 39%. In Koplik and Crohn's case [6] the nitrogen absorption was 86.2% and the fat absorption 48.4%. Very much less than the normal amount of fat was split. Similar types of stools with large amounts of unsaponified fat have been observed by us clinically.[7] These figures show that in the infant as well as in the adult, bile is necessary for the normal splitting and absorption of fat.

Tubercular peritonitis in babies is primarily a disease of the lymphatic system and when the mesenteric glands become caseous they form a dam beyond which the fat cannot pass. It has been shown earlier that most of the fat is normally carried by the lymphatics to the blood stream. If this road is blocked with tuberculous tissue, it is reasonable that some of the fat should be lost from the body. Talbot [8] studied cases with tuberculosis of the mesenteric glands and found that in all cases in which a large proportion of these glands were involved there was a loss of fat through the intestines. Hecht [9] believes that 8% of the fat in the stool should be split, and considers that great divergence from

[1] Wentworth: Boston Med. and Surg. Jour., 1910, clxii, 869, and Archives Int. Med., 1910, vi, 420.

[2] Meyer, L. F.: *loc. cit.*

[3] Hecht: "Die Faeces des Säuglings und des Kindes," Berlin-Wien, 1910, 128.

[4] Reuss: Case of Obliterated Bile Duct (congenital) Reported in Discussion,—Jahrb. f. Kinderh., Dec., 1908, 729.

[5] Niemann: Zeitschr. f. Kinderh., 1912, iv, 152.

[6] Koplik and Crohn: Am. Jour. Dis. Children, 1913, v. 36.

[7] Morse, J. L.: Boston Med. and Surg. Jour., 1910, clxii, 238.

[8] Talbot: Am. Jour. Dis. Children, 1912, iv, 49. (See literature.)

[9] Hecht: *loc. cit.*

this amount means either trouble with the bile or pancreatic juice. He reports the case of a seven months, premature baby which was able to split only 53% of the fat, and considers this to be due to weak action of the pancreatic fat-splitting enzyme, which presumably is not completely developed. Finizio [1] explains a large amount of fat in the stool of an eleven months old baby ill with mumps by probable trouble in the pancreas. In this case 75% of the dried stool was fat, and of this only 7% was soaps, while 11% was fatty acid and 82% neutral fat.

Czerny [2] believes that babies with an exudative diathesis can be harmed by fat. He finds that an increase in the amount of fat in the food will bring out eruptions on the skin. Steinitz and Weigert [3] have apparently proved the correctness of this assumption by a metabolism experiment.

Towle and Talbot [4] studied the digestion of infants ill with eczema and found that in a large number of cases the severity of the skin eruption bore a direct relation to the fat in the food. This was by no means the case in all instances, but there was a sufficient number to substantiate Czerny's findings.

There is no doubt that large amounts of fat can do a great deal of harm to most babies. Such babies come under two classes,—those which have a normal digestion and are unable to digest excessive amounts of fat, and those which have diminished powers of digestion and are unable to digest normal amounts of fat. So much attention has been paid to the few babies that are unable to digest fat that we are apt to forget that most babies can digest fat within reasonable limits. L. F. Meyer [5] has shown in Finkelstein's clinic that when fat is increased in the food of normal healthy babies there is no loss of fat or salts from the body. This dispels, in a very convincing way, the false impression that normal babies are unable to digest fat. Howland has shown in a recent investigation (not yet published) that a baby can be fed on large quantities of fat without symptoms of indigestion and without acidosis.

[1] Finizio: Pediat. Sept., 1909, 674; Rev. in Archiv. f. Kinderh., 1910, liv. 461.

[2] Czerny: Part I, Monatschr. f. Kinderh., 1906, iv, 1; ibid., Part II, 1908, vi, 1; ibid., Part 3, 1909, vii, 1.

[3] Steinitz and Weigert: Monatschr. f. Kinderh., 1910, ix, 385.

[4] Towle and Talbot: Am. Jour. Dis. Children, 1912, iv, 219.

[5] Meyer, L. F.: Jahrb. f. Kinderh., April, 1910, 379.

CHAPTER III

THE DIGESTION AND METABOLISM OF CARBOHYDRATES

FERMENTS

Saliva.—Zweifel [1] found diastase in the parotid gland of the newly-born, but was unable to find it in the submaxillary. Ibrahim,[2] after prolonged investigations, found it in both the parotid and submaxillary glands, its action being stronger in the former than in the latter. Diastase was found much earlier in fetal life in the parotid than in the submaxillary, traces being found in the former at the fourth and in the latter at the sixth month of fetal life. The diastase of the parotid is the earliest digestive ferment found in the embyro.

A diastatic ferment can always be found in the saliva of healthy infants.[3] The diastatic action of saliva may continue in the stomach as long as two hours after feeding.[4]

Stomach.—Ibrahim [5] is the only worker who has examined the gastric mucous membrane of the newly-born for the carbohydrate splitting ferments, and he has been unable to find either lactase, maltase or invertin.

Pancreas.—Moro [6] was able to demonstrate the presence of an amylolytic ferment in the pancreas of newly-born babies when the pancreas was thoroughly extracted, and thus disproved the earlier work of Zwiefel and Korowin. Ibrahim [7] never failed to get the ferment in a six months' fetus when he tested the action of the ferment on starch meal. He was, however, unable to find it when he tested soluble (*i. e.*, cooked) starch.

[1] Zweifel: Untersuchungen über den Verdauungsapparat der Neugeborenen, Berlin, 1874.

[2] Ibrahim: Verhandl. d. Gesell. für Kinderh., Köln, 1908, p. 21.

[3] Schiffer: Berl. klin. Wochenschr., 1872, ix, 353; Korowin: Jahrb. f. Kinderh., 1875, viii, 381; Zweifel: *loc. cit.;* Schlossmann: Jahrb. f. Kinderh., 1898, xlvii, 116; Montagne: Dissertation, Leyden, 1889, quoted in Czerny and Keller,—"Des Kindes Ernährung," etc.; Schilling: Jahrb. f. Kinderh., 1903, lviii, 518.

[4] Shaw: Albany Med. Ann., 1904, xxv, 148.

[5] Ibrahim: *loc. cit.*

[6] Moro: Jahrb. f. Kinderh., 1898, xlvii, 342.

[7] Ibrahim: *loc. cit.*

Ibrahim was unable to demonstrate invertin and lactase in the pancreas of newly-born or older babies, but he was usually able to demonstrate maltase in the newly-born and always in older children. Maltase may also be found in the blood.

Small Intestine.—The mucous membrane of the small intestine contains amylolytic ferments.

Lactase, the ferment which splits milk sugar, has been repeatedly found in the mucous membrane of the small intestine.[1] Ibrahim always found it in the small intestine and meconium of newly-born babies, but was unable to find it in premature infants. He says, however, that his method of determining lactase is not capable of demonstrating small amounts. Lactase is more abundant in young animals than in the adult.

Pautz and Vogel found maltase, the ferment which splits malt sugar, in the small intestine of infants.

Invertin, the ferment which splits cane sugar, was found in the secretions of the small intestine of the newly-born by Miura [2] and Ibrahim was always able to demonstrate its presence both in the intestinal mucous membrane and in the intestinal contents of all fetuses.

Large intestine.—It is difficult to wash the large intestine free from meconium, and the results of the examinations of its mucous membrane are variable, as the tables of Miura, Pautz and Vogel show. It is, therefore, impossible to say whether it contains ferments or not.

Stools.—Pottevin [3] found an amylolytic ferment in the meconium. Kerley, Mason and Craig [4] were able to demonstrate the presence of a strong amylolytic ferment in the stools of very young babies, the possibility of the bacterial fermentation of starch being excluded. There is a larger amount of diastase in the stools of breast-fed babies than in those of the bottle-fed, which Hecht [5] believes to be due to the fact that the intestinal contents of the breast-fed baby pass more quickly through the intestinal canal than do those of the bottle-fed baby. The power of digesting starch, while occasionally absent is, therefore, almost always present both in the fetus and in the newly-born. Hess [6] always found it present during the first week of life, the amount of the

[1] Pautz and Vogel: Zeitschr. f. Biol., 1895, xxxii, 304; Weinland: ibid., 1899, xxxviii, 16; Orbán: Prag. med. Wochenschr., 1899, xxiv, 427.

[2] Miura: Zeitschr. f. Biol., 1895, xxxii, 266.

[3] Pottevin: Compt. rend. de la Soc. biol., 1900, lii, 589.

[4] Kerley, Mason and Craig: Arch. Pediat., 1906, xxiii, 489.

[5] Hecht: "Die Fæces des Säuglings und des Kindes," Berlin, 1910.

[6] Hess: Am. Jour. Dis. Children, 1912, iv, 205.

ferment increasing with the age of the infant. Young babies are, nevertheless, able to adapt themselves to a food rich in carbohydrates. There is according to Moro,[1] a rapid increase in the power of digesting starch during the first week of life. The baby, therefore, has a power of digesting starch at birth which gradually increases in strength as the baby grows older. According to Finizio [2] it is twice as strong at eight months as it is at birth, while at twelve months it is almost as strong as at three years.

The question whether the carbohydrate-splitting ferments are affected by disease has been answered only in part. Orbán [3] found by animal experimentation that an injured intestinal mucous membrane contained no lactase, and that the stools of babies ill with enteritis contained no lactase. Langstein and Steinitz [4] on the other hand, always found lactase in the stools of babies ill with enteritis, whether mild or severe, acute or chronic. Nothmann [5] was unable to demonstrate lactase in the stools of seven premature babies on the first day post partum, but found it always after milk had been fed.

FORMS OF CARBOHYDRATES

The forms of carbohydrates commonly used in infant feeding may be divided into the groups given in the following table (taken from Reuss [6]).

TABLE 11

Milk sugar group	*Cane sugar group*	*Malt sugar group*
		Starch (Amylum)
		↕
		Dextrin (Amylo-dextrin)
		↕
		Erythro & Achro-dextrin
		↕
Lactose (milk sugar)	Saccharose (cane sugar)	Maltose (malt sugar)
↕	↕	↕
Dextrose + Galactose	Dextrose + Levulose	Dextrose + Dextrose

[1] Moro: Jahrb. f. Kinderh., 1898, xlvii, 342.
[2] Finizio: Rev. d. Hyg. et Med. Inf., 1909, viii, 224.
[3] Orbán: Prag. med. Wochenschr., 1899, xxiv, 427.
[4] Langstein and Steinitz: Hoffmeister's Beitrage, 1909, vii, 575.
[5] Nothmann: Monatsschr. f. Kinderh., 1909–10, viii, 377.
[6] Reuss: Wien. med. Wochenschr., 1910, lx, Nos. 28, 29, 30.

DIGESTION OF CARBOHYDRATES

The carbohydrates are broken down during digestion into the simplest forms of sugar, the monosaccharides, by the various ferments described above. According to Rohmann [1] a considerable amount of the di-saccharides may pass into the intestinal mucous membrane and there be split into mono-saccharides. The mono-saccharides are carried from the portal vein to the liver, where they are transformed into glycogen, the only difference being that dextrose is more easily converted than levulose or galactose.[2] The pancreas has some influence on this process because extirpation of the pancreas in dogs results in sugar in the urine and interferes with the formation of glycogen in the liver. The liver actually has the property of forming glycogen from sugar.[3]

The purpose of the splitting of the poly- and di-saccharides into mono-saccharides is to prepare them for use inside the body, because the unsplit carbohydrates are not burned up in the body, but are excreted in the urine. The transformation of sugar into glycogen which is deposited in the liver and muscles, is of great importance because this glycogen can be converted again into sugar according to the needs of the body.

There is normally about 1–10% of dextrose in the blood. The slightest disturbance of the regulating apparatus will cause a hyperglycemia which results in glycosuria. A deficit of sugar in the blood is made up from the glycogen deposits.[4] The mono-saccharides are absorbed more quickly than the di-saccharides.[5]

A large part of the digestion and absorption of the carbohydrates takes place in the upper part of the small intestine.[6] Splitting and absorption may also take place in the large intestine.[7]

The bacteria of the stomach and intestines attack not only cellulose but other carbohydrates as well. The decomposition of the carbohydrates by means of bacteria, in general, is not very extensive and depends very much on the external conditions. The products formed by their action are chiefly lactic acid, acetic acid,

[1] Rohmann: Pfluger's Arch. 1903, xcv, 533.

[2] Alderhalden: Textbook of Physiological Chemistry, London, 1908.

[3] Grube: Pfluger's Arch., 1905, cvii, 490.

[4] Langstein-Meyer: Säuglings Ernährung und Sauglingsstoffwechsel, Wiesbaden, 1910.

[5] Hédon: Compt. rend. de la Soc. de Biol., 1900, 29; Nagano: Pfluger's Archiv., 1902, xc, 389; Rohmann: Chem. Bei., 1895, xxviii, 2506.

[6] London and Polowzowa: Zeitschr. f. physiol. Chem., 1906, xlix, 328.

[7] Reach: Arch. f. exp. Path u. Pharm., 1902, xlvii, 230; Schönborn: Diss. Würzburg, 1897; Pehu and Porcher: Rev. d'Hyg. et de Med. Inf., 1910, ix, 1.

formic acid, butyric acid and alcohol with, in addition, the evolution of carbon dioxide, hydrogen, and methane.[1] In abnormal conditions the bacteria probably play a much more important part in the breaking down of carbohydrates.

Little or no sugar can be found in the stools under normal conditions, but when the food passes quickly through the intestinal canal, as it does when the peristalsis is increased as the result of disease or indigestion, sugar may be found in the stools (Hecht). Usually, only the products of the decomposition of sugar can be isolated.

Hedenius [2] fed babies on milk mixed with wheat flour, oat gruel or Keller's malt extract and measured the amount of carbohydrate ingested, the amount found in the stools, and the acidity of the stools. He found less carbohydrate in the stools when simple cereals were used than when the more complicated mixtures were given. He also found that the more carbohydrate there was in the stool, the greater was its acidity. He never found more than three per cent of the ingested carbohydrate in the stools.

Raczynski [3] has shown that in babies sick with what he calls "dyspepsia intestinalis acida lactorum," the acidity of the intestinal contents is increased and the utilization of fat diminished.

Talbot and Hill [4] found in their case (J. P.), that an increasing amount of lactose in the food did not appreciably influence the titratable acidity of the stool until a diarrhea commenced. The acidity then increased five hundred per cent and lactic, acetic, succinic and butyric acids were found to be present. This fact seemed to indicate that the acid-forming bacteria played an important part in the breaking down of the sugar.

Keller [5] has shown that carbohydrates make the digestion of protein more complete. Talbot and Hill [6] have recently confirmed these findings. A possible explanation of the protein-sparing action of carbohydrates may be found in the work of Kendall and Farmer [7] on the metabolism of bacteria. They found that in the test-tube, when sugar was present in the food, less ammonia nitrogen was formed than when sugar was absent. If the results obtained in the test-tube are applicable to the intestinal canal, the

[1] Tappeiner, H.: Zeitschr. f. Biol., 1883, xix, 228.
[2] Hedenius: Ueber das Schicksal der Kohlehydrate im Säuglingsdarm.
[3] Raczynski: Wien. klin. Wochenschr, 1903, xvi, 342.
[4] Talbot and Hill: Am. Jour. Dis. Children, 1914, viii, 218.
[5] Keller: "Des Kindes Ernährung," etc.,—*loc. cit.*
[6] Talbot and Hill: Am. Jour. Dis. Children, 1914, viii, 218.
[7] Kendall and Farmer: Jour. Biol. Chem., 1912, xii, 13; 1912, Nos. 1, 2 and 3; 1912–13, xiii, 63.

reason that more nitrogen is retained in the body when sugar is present is not because the sugar makes the nitrogen more easily absorbable, but because the intestinal bacteria use the sugar in preference to the protein and form less nitrogen to be carried away in the stools. In other words, the bacteria leave a larger amount of nitrogen for absorption than when they grow on a sugar-free protein.

Albertoni [1] and Hédon [2] found that sugars have a purgative action when they are given in large enough amounts. This action is more marked when they are taken in concentrated solution. All sugars have this action, the difference between them being only in degree. They found that glucose and cane sugar are much more quickly absorbed than lactose, and that glucose has less of a purgative action than the cane sugar. According to the extensive experiments of Rohmann and Nagano [3] saccharose is absorbed more quickly than maltose.

METABOLISM OF CARBOHYDRATES

Numerous observations [4] have shown that when milk sugar is injected directly into the circulation it may be completely recovered in the urine. Grosz [5] was never able to detect milk sugar in the urine of healthy babies, but found it in the urine of those suffering with gastrointestinal disease, in which there was presumably an absence of lactase in the intestine. Langstein and Steinitz [6] repeated Grosz's experiments and in certain instances found lactase in the stools at the same time that sugar was being excreted in the urine. This sugar was, moreover, not always lactose, but sometimes galactose, one of the products of the splitting of lactose. They tried to explain this as follows:—That some of the sugar passes through areas of the intestinal wall made abnormal by functional or anatomical lesions before it is completely broken up and it is excreted in the urine as an intermediary product of metabolism.

Mendel and Keliner [7] have shown that when cane sugar is introduced subcutaneously into dogs or cats in doses of one to two

[1] Albertoni: Arch. ital. de Biol., xv, xviii, xxx, xxxv, xxxviii, xl.

[2] Hédon: Compt. rend. de la Soc. de Biol., 1899, 884; ibid., 1900, 29 and 87.

[3] Rohmann and Nagano: quoted by Hammarsten and Mandel, "Textbook of Physiological Chemistry, New York, 1912, 509.

[4] Voit: Deutsch. Arch. für klin. Med., 1897, lviii, 523.

[5] Grosz: Jahrb. f. Kinderh., 1892, xxxiv, 83.

[6] Langstein and Steinitz: Moffmeister's Beitrage, 1906, vii, 575.

[7] Mendel and Keliner: Am. Jour. Physiol., 1910, xxvi, 396.

grams per kilogram of body weight it is not completely recovered in the urine. The quantity excreted amounts as a rule to more than 65% of that introduced. The excretion begins within a few minutes and is usually completed within thirty-six hours. Fisher and Moore [1] draw attention to the possibility that the sugar thus introduced may be excreted through the walls of the alimentary tract and there be digested. These views are supported by Jappelli and D'Errico,[2] who conclude from their experiments on dogs that when cane sugar is introduced directly into the circulation the quantity eliminated in the urine is never equivalent to the amount injected. This causes both glycosuria and saccharosuria, the former disappearing first. The blood has no power of converting cane sugar. According to these writers cane sugar introduced intravenously is eliminated into the alimentary tract through the gastric mucosa, the salivary glands and, to an insignificant degree, through the bile. The subsequent fate of this component is obvious.

In the year 1906, Finkelstein published the first of a series of papers [3] which have caused much discussion as to the etiology of the digestive disturbances of infancy. In the first place he opposed Czerny's teachings as to the harmfulness of fat in infant feeding. He taught that bacteria played no part in the etiology of the digestive disturbances of infancy and that the sugars produced symptoms of intoxication. He also undertook to prove that the albumens were quite harmless. He considered that the most acute form of disease of the digestive tract, that accompanied by stupor, fever, and sugar in the urine, was the result of an intoxication caused by sugar. He blamed lactose for the poisoning of the system, and claimed that instantaneous benefit and cure resulted from the complete withdrawal of sugar. Schaps [4] and Leopold and Reuss [5] also thought that lactose and other sugars were pyrogenic. In 1909, Finkelstein said,—"It is possible, with the certainty of an experiment, by giving a dose of sugar (for example 100 grams of a 12.5% lactose solution), to an infant with bowel trouble to

[1] Fisher and Moore: Am. Jour. Physiol., 1907, xix, 314.

[2] Jappelli: Ref. Maly's Jahresbericht für Tierchemie, 1905, xxxv, 79.

[3] Finkelstein: Verhandl. Gesellsch. f. Kinderh. (Stuttgart), 1906, xxiii, 117; Jahrb. f. Kinderh., 1907, lxv, 1 and 263; Jahrb. f. Kinderh., 1908, lxviii, 521; Deutsch. med. Wochenschr., 1909, xxxv, 191; Finkelstein and Meyer: Jahrb. f. Kinderh., 1910, lxxi, 525 and Berliner klin. Woch., 1910, xlvii, 1165. For literature and an excellent discussion of the subject, see chapter on "Sugar in the Young" in Allen,—"Glycosuria and Diabetes," Harv. Univ. Press, 1913.

[4] Schaps: Verhandl. Gesellsch. f. Kinderh., 1906, xxiii, 153; Berliner klin. Wochenschr., 1907, xliv, 597.

[5] Leopold and Reuss: Monatschr. f. Kinderh., 1909-10, viii, 1 and 453.

force up the previously afebrile temperature into fever, practically with the same certainty as if one should give it a dose of tuberculin." Later, he found that fever also resulted when physiological salt solution was given by mouth. His "eiweissmilch" was prepared to cure sugar intoxications. He apparently overlooked the fact that it contained 1½% or more of the lactose which he considered so poisonous in this condition. As his theories developed, he decided that the sugar intoxication was not due to a sugar injury alone, but to the actions of salts, especially the chlorine-ion combination with sodium. Friberger,[1] Schloss,[2] Cobliner,[3] and Nothmann,[4] confirmed Meyer's statements concerning the pyrexial effects of sodium-halogen compounds, while Rosenthal [5] found that in animals neither salt nor sugar had any specific pyrogenic action.

In 1910 Finkelstein and Meyer ascribed intestinal irritation to abnormal fermentations. They stated that casein was never harmful and that it prevented or diminished acid fermentation. They stated, on the other hand, that, as Czerny pointed out, fat was more dangerous, but claimed that it was only harmful in a bowel irritated by carbohydrate fermentation. They admitted, at this time, that human milk was the best food to give in these conditions, thus abandoning their earlier contention that lactose (which is present in large amounts in human milk) is poisonous.

Helmholz [6] found that 5% solutions of sodium chloride, bromide, and iodide injected into rabbits subcutaneously in quantities of from ten to twenty-five cubic centimeters caused no rise of temperature in the great majority of experiments. Sodium chloride produced a slight rise in temperature when given intravenously in high concentration. A 1% solution of sodium chloride may, in exceptional instances, produce a febrile rise in temperature when given by mouth. Schlutz [7] confirmed these findings; he found that lactose alone possesses no distinct pyrogenic action, but that it may affect the temperature if it is given in combination with a sodium salt when the intestinal tract is diseased.

Allen [8] studied the effects of sugars in young, nursing animals and found that in no instance were there any symptoms of the intoxicating action of sugar, even when the animals received so

[1] Friberger: Münch. med. Wochenschr., 1909, lvi, 1946.
[2] Schloss: Biochem. Zeitschr., 1909, xviii, 14.
[3] Cobliner: Zeitschr. f. Kinderh., ii, 429.
[4] Nothmann: Zeitschr. f. Kinderh., i, 73.
[5] Rosenthal: Jahrb. f. Kinderh., 1909, lxx, 123.
[6] Helmholz: Arch. of Internal Medicine, 1911, vii, 468.
[7] Schlutz: Am. Jour. Dis. Children, 1912, iii, 95.
[8] Allen: "Glycosuria and Diabetes," Harvard Univ. Press, 1913.

much sugar by mouth that they had vomiting and diarrhea. He found, furthermore, that subcutaneous injections of glucose had a very beneficial action on animals, even when they had glycosuria and were doing badly. The evidence at hand is opposed to the belief that sugar has any specific intoxicating effect or acts as a food poison and is in favor of the theory [1] that it is a medium of growth for bacteria in which they can develop sufficiently to harm the body either by their own activity or by the products which result from their activity.

The limits of assimilation of the different sugars vary and are given as follows:

Grape sugar: In babies, about 5 grams per kilogram (Langstein and Meyer).

Grape sugar: In one month baby, 8.6 grams per kilogram (Greenfield).[2]

Galactose: No accurate data.

Levulose: (Lower for babies than adults), one gram per kilogram (Keller).

Maltose: Over 7.7 grams per kilogram (Reuss).

Lactose: From 3.1–3.6 grams per kilogram (Grosz).

Cane sugar: Probably about the same as lactose (Reuss).

The main facts which are apparently true about the metabolism of carbohydrates in infancy are:—carbohydrates are absorbed up to a certain point, lactose being absorbed more slowly than the other di-saccharides. Up to a certain point lactose and maltose increase the retention of nitrogen, but apparently have no influence on the retention of ash or the absorption of fats. Beyond that point there is a marked increase in the acidity of the intestinal canal which results in increased peristalsis, and which washes the irritating food out of the bowels as quickly as possible. Large amounts of fat, protein and ash are carried out in the stools, resulting in a diminished absorption and retention of these food components.

Starches act in the same manner as the other carbohydrates except that having a more complicated molecule, they go through one more step in the process of their conversion into a monosaccharide.

[1] Escherich: Deutsche Klinik, 1902, vii, 126.

[2] Greenfield: Jahrb. f. Kinderh., 1903, lviii, 666.

CHAPTER IV

THE DIGESTION AND METABOLISM OF PROTEIN

FERMENTS

The saliva of man was shown to contain a proteolytic ferment by Ed. Müller,[1] but up to date such a ferment has not been found in infants.

Pepsin was first demonstrated in the mucous membrane of the infant's stomach by Zweifel[2] and later Langendorff[3] extracted it with HCL from the stomach of a fetus of four months, at which time there is microscopic evidence of glandular formation. The amount of pepsin increases with the age of the baby up to the third month, and from then on remains constant in amount; it is present in larger quantities in bottle-fed babies than in breast-fed babies.[4] Pechstein[5] examined the urines of babies at different ages and under different conditions and found that all babies excrete pepsin and rennin in their urine from the day of their birth onward. These ferments are present only in the form of their pro-ferments. They are found in minute quantities in the early days of life and increase in amount up to the end of the first year, at which time there is about one twentieth as much as in the adult. The urine of the artificially-fed baby contains more than does that of the breast-fed baby. During an acute disturbance of digestion they are as abundant as in health, but during chronic diseases they seem to be slightly diminished in amount. When pepsin and rennin are fed to a baby, no traces are found in the urine, and there is no increase in the amount of rennin in the stool. The ferments must, therefore, have been destroyed in the upper intestine or neutralized in the blood stream. If the intestinal mucous membrane is damaged, the ferments appear in the urine.

Rennin and hydrochloric acid are found in the first days of

[1] Ed. Müller: Verhandl. d. Cong. für inn. Med., 1908, 676.

[2] Zweifel: Untersuchungen über den Verdauungsapparat der Neugeborenen, Berlin, 1874.

[3] Langendorff: Arch. für Anat. u. Physiol., 1879, 95.

[4] Rosenstern: Berl. klin. Wochenschr., 1908, 542.

[5] Pechstein: Zeitschr. f. Kinderh., 1911, i, 365.

life.[1] Rennin has been demonstrated in sterile meconium [2] and a rennin ferment which acts independently of the stomach and pancreas [3] has been found in the stool.

Trypsin.—Zweifel demonstrated trypsin in the pancreatic extracts of new-born babies, and Langendorff found it at the beginning of the fifth month of fetal life. Ibrahim [4] showed that when absolutely fresh material was used only the pro-ferment trypsinogen is present in the pancreas of the fetus, but that small amounts of trypsin may be present in the pancreas of older children. This can be markedly increased by activating it with enterokinase. The pro-ferments are apparently activated by bacteria, which are, of course, not present in the intestinal canal of the fetus. He was able to demonstrate trypsinogen in a six-months-old fetus.

Trypsin is found in the feces in small amounts in health and in large amounts during diarrhea caused either by drugs or disease. Sterile meconium has the property of dissolving gelatine.[5] Hecht [6] demonstrated trypsin in the stools of babies as early as the first day of life.

Wienland [7] found anti-pepsin in the stomach and anti-trypsin in the intestinal mucous membranes; he believed that their function was to prevent auto-digestion. Cohnheim [8] believes that anti-trypsin is identical with enterokinase and that in small amounts it activates trypsin, and in large amounts prevents its action.

Enterokinase.—The ferment which activates trypsinogen was first found by Ibrahim, who extracted it from the intestinal mucous membrane of new-born babies, and from meconium. It is most active in the lower third of the intestine in the majority of instances; it may also be obtained from the mucous membrane of the large intestine. It apparently first appears in embryonic life at the same time that trypsin is found in the pancreas.

Secretin, according to Baylies and Starling,[9] is necessary for the activation of the pancreas. It may be extracted from the intestinal mucous membrane; it is not destroyed by heat, and belongs to the group of hormones. When injected intravenously it

[1] Szydlowski: Jahrb. f. Kinderh., 1892, xxxiv, 411.
[2] Pottevin: Compt. rend. de la Soc. de Biol., 1900, lii, 589.
[3] Th. Pfeiffer: Zeitschr. f. Exp. Path. u. Therap., 1906, iii, 381.
[4] Ibrahim: Gesellschaft Deutscher Naturforscher und Ärtzte in Coln, 1908.
[5] Pottevin: *loc. cit.*
[6] Hecht: Wien. klin. Wochenschr., 1908, xxi, 1550.
[7] Wienland: Zeitschr. f. Biol., 1903, xliv, pt. I.
[8] Cohnheim: Nagel's Handbuch d. Physiol., 1907, ii, 597.
[9] Baylies and Starling: Jour. Physiol., 1902, xxviii, 325.

causes a flow of pancreatic juice in about one minute. Ibrahim and Gross [1] found it in babies who died at birth, but not in premature babies. Wentworth [2] found it absent or present only in small amounts in newly-born babies. He found definite but weak action in a premature baby which had lived three weeks. Older babies, which had died of other diseases than those of the digestive tract, all showed a definitely active secretin. Hallion and Lequeux [3] found secretin in the upper part of the intestine of two newly-born babies, but were unable to find it in the lower part of the intestine. They obtained the same results in a five months' fetus. There is no record of secretin being found in the feces.

Erepsin was first demonstrated in the intestinal mucuous membrane by Cohnheim.[4] It changes albumoses and peptones very rapidly into amino- and diamino-acids, so that the Biuret reaction disappears. It has no action upon the native albumens with the exception of casein. It is present in all babies, including premature infants.[5]

Lust [6] found an anti-proteolytic ferment in the blood of an infant fourteen days old, which had the same anti-tryptic power as that in the blood of an infant of one year. There is no increased formation of this ferment in digestive disorders, while in some cases of alimentary intoxication, in which there is loss of protein from the body, there is an increased amount of the anti-ferment.

Mitra [7] was unable to find nuclease or connectivase which could digest muscle fibre and connective tissue in the stomach of an infant twelve months old, but found both ferments in a child of fifteen months. Rossi [8] measured the stimulating effect of saliva on the pepsin digestion by the Mett method. He found it greatest in the early stages of digestion but it became almost imperceptible at the end of four hours. Wakabayashi and Wohlgemuth [9] found that the large intestine contains erepsin, nuclease, hemolysin and a fibrin enzyme.

The changes which protein undergoes during digestion may be briefly enumerated as follows:

[1] Ibrahim and Gross: Jahrb. f. Kinderh., 1908, lxviii, 232.
[2] Wentworth: Jour. Am. Med. Assoc., 1907, 119, 204.
[3] Hallion and Lequeux: Compt. Rend. de la Soc. de Biol., Paris, 1906, lxi, 33.
[4] Cohnheim: Zeitschr. f. Physiol. Chemie. Mitteilungen über das Erepsin, 1902, xxxv, 134. Notiz über das Erepsin, 1906, xlvii, 286.
[5] Langstein: Jahrb. f. Kinderh., 1908, lxvii, 9.
[6] Lust: München Med. Wochenschr., lvi, 2047–2051.
[7] Mitra: Folia clinica, iii, 274.
[8] Rossi: Arch. Fisiol., viii, 484; from Zentralbl. Biochem. u. Biophys., ii, 436.
[9] Wakabayashi and Wohlgemuth: Internat. Beitr. Path. Therap., ii, 519.

When it is ingested it is split and hydrolyzed by the various ferments in a definite sequence. Pepsin reduces it into albumoses and peptones. Trypsin and erepsin then split these bodies further into amino acids, with an intermediary stage of polypeptides. The end products of protein digestion are amino acids and their combinations.

Folin and Denis [1] and Van Slyke and Meyer [2] showed that the amino acids are absorbed as such from the alimentary tract. The evidence adduced by these observers that the amino acids reach the blood stream as amino acids and are carried to the tissues to be used in the formation of new tissue or to be disintegrated with the resultant production of the end product urea, has been strengthened by the work of London.[3] During digestion the amount of amino-nitrogen increases not only in the portal blood but also in the peripheral circulation.

CASEIN CURDS

Twenty-eight years ago Biedert [4] published the first of a series of papers, in which he tried to show that many of the disturbances of digestion in infancy were due to difficulty in digesting casein. He believed that the bean-like masses which appeared in the stools of artificially-fed babies during disturbances of digestion were either casein or one of its derivatives. He found that their microscopic appearance was similar to that of coagulated casein and that they turned pink with Millon's reagent. Wegscheider,[5] Uffelmann,[6] Escherisch,[7] and Fr. Müller [8] were unable to confirm Biedert's assumption and concluded from their own experiments that the "so-called casein curds" were formed of calcium soaps, epithelium, bacteria, and intestinal secretions. It was shown, furthermore, that Biedert's methods of proving the presence of casein [9] were of no positive value since nucleo-protein and nucleo-albumen gave the same tests.[10]

[1] Folin and Denis: Jour. of Biol. Chem., 1912, xi, 87 and subsequent papers.
[2] Van Slyke and Meyer: Jour. Biol. Chem., 1912, xii, 399.
[3] London: Zeitschr. f. Physiol. Chem., 1913, lxxxvii, 313.
[4] Biedert: Jahrb. f. Kinderh., 1888, xxviii, 21.
[5] Wegscheider: Ueber normale Verdauung bei Sauglingen. Innaug. Diss. Strassburg, 1875; cited by Blauberg: Experimentelle und kritische Studien über Sauglingsfeces bei naturliche u. kunstlicher Ernährung, Berlin, 1897.
[6] Uffelmann: Deutsch. Arch. f. klin. Med., 1881, xxviii, 437.
[7] Escherisch: Jahrb. für Kinderh., 1888, xxvii, 100.
[8] Fr. Müller: Zeitschr. für Biol., 1884, xx, 327.
[9] Biedert: Arch. f. Gynak., 1907, lxxxi, 1.
[10] See also Southworth and Schloss: Arch. Pediatrics, 1909, xxvi, 241.

Talbot [1] showed that there are two kinds of curds, one of which is large and tough and contains a high percentage of protein, and the other which is small and soft and contains a low percentage of nitrogen and a high percentage of fat. The former are tough, bean-like masses of varying size and shape, weighing from ¼ to 1½ gm., the color varying from white to greenish-yellow according to how much they are stained by the bile and intestinal secretions. They may be easily separated from the fecal material in which they are imbedded and become extremely hard when treated with 10% formaline solution. These curds are the ones examined by Biedert. The small, soft curds are either flat, white flakes (which look like undigested particles of milk) or pinhead elevations, which are stained green or yellow by the intestinal secretions. They are always associated with more or less mucus and are composed almost entirely of fat in the form of fatty acids or soaps. These curds are probably the ones examined by Biedert's opponents.

Knopfelmacher [2] and Selter [3] examined the tough curds chemically and concluded that they were composed of casein.

The chemical composition of casein curds is as follows:

TABLE 12

Author	*Fat in food %*	Curds		*Neutral fat. % of dried stool*	*Fatty acid.% of dried stool*	*Soaps. % of dried stool*
		Nitrogen. % of dried stool	*Total fat. % of dried stool*			
Talbot [4]	3.75	7.2	46.8	36.4	4.6	5.8
	3.50	9.8	28.	21.4	1.2	5.6
Benjamin [5]....	"Eiweissmilch"	10.4	27.			
Courtney [6]	2.3	10.6	22.3			
	1.8	10.6	19.0			
Talbot [4]	"Fat free milk"	12.0	8.4	2.2	0.8	5.4

The foregoing table gives analyses of selected curds from three investigators and shows the general tendency for the amount of fat in the curd to increase with the amount of fat in the milk.

[1] Talbot: Boston Med. and Surg. Jour., 1908, clviii, 905; and ibid., Jan. 7, 1909.

[2] Knopfelmacher: Wien. klin. Wochenschr., 1898, 1024; ibid., 1899, 1015; ibid., 1899, No. 52, 1038; and Jahrb. f. Kinderh., 1900, lii, 545.

[3] Selter: Verhandl. d. Gesellsch. f. Kinderh., Stuttgart, 1906, 177.

[4] Talbot: Boston Med. and Surg. Jour., 1908, clviii, 905.

[5] Benjamin: Zeitschr. f. Kinderh., 1914, x, 185.

[6] Courtney: Am. Jour. Dis. Children, 1912, iii, 1.

Conversely the amount of nitrogen diminishes as the fat increases. This seems to indicate that fat, the accidental component of the curd, dilutes the nitrogen.

These experiments were not considered conclusive by most pediatricians, especially those of the schools of Czerny, Finkelstein and Heubner, while Biedert and many American schools thought that they were casein. Wernstedt [1] compared under the microscope and microchemically the tough curds found in the stool with those found in the stomach and concluded that they were casein.

Recently, Talbot, Bauer, Uffenheimer and Takeno [2] working at approximately the same time with different methods, showed by the precipitine method, by anaphylaxis, and by complement fixation that the protein in tough curds was cow casein. None of these methods were sufficiently fine to tell whether some of the casein was changed into paracasein or not.

When milk curdles in the infant's stomach it entangles a large proportion of the milk fat in its meshes and only such fat as lies near the surface of the curd can be reached by the digestive juices. The amount of fat in the curd depends upon the amount of fat in the milk.[3] Courtney [4] did not find any great variation in the percentage of fat in the curds examined by her. This is what would be expected, because there was no great variation in the percentage of fat in the food of the babies passing the curds. She went further, however, and examined the stool mass surrounding the curds and concluded that the casein curds are not pathognomonic of any pathological condition, and that the loss of food occasioned by their formation and the impairment of the general nutrition resulting from it is insignificant. Finally, that in attempting to correct the state of digestion one should be guided by the general rules of infant feeding, paying only secondary attention to the appearance or disappearance of curds from the stools.

Howland [5] believes that the presence of casein curds in the stools is of "limited, if any, pathological importance, but rather depends on physical conditions in the gastrointestinal tract." Benjamin [6] notes that casein curds appear in the stools of healthy as well as

[1] Wernstedt: Hygiea, 1907, No. 9, ref. München Med. Wochenschr., 1907, 2543.

[2] Talbot: Arch. Pediat., 1910, xxviii, 440; Uffenheimer and Takeno: Zeits. f. Kinderh., 1911, ii, 32; Bauer: Monatschr. f. Kinderh., 1911, x, 239.

[3] Talbot: *loc. cit.*

[4] Courtney: Am. Jour. Dis. Children, 1912, iii, 1.

[5] Howland: Am. Jour. Dis. Children, 1913, v. 390.

[6] Benjamin: Zeitschr. f. Kinderh., 1914, x, 185.

of dyspeptic infants and that there is less gain in weight while these curds are being passed than when they are absent. There is no question, however, that the casein curds are relatively rare in infants' stools and that their presence is often associated with symptoms of indigestion.

Ibrahim [1] and Brennemann [2] observed that the casein curds appeared in the stools of babies fed on raw milk and disappeared from the stools when the milk was boiled. They both suggest boiling as a therapeutic measure for preventing the formation of such curds. This fact explains why casein curds are seldom seen in Germany where the milk is almost universally boiled.

Ibrahim observed that the curds seem to come more easily in babies with digestive disturbances, but that they may come in otherwise healthy babies who are fed on raw milk. He saw them in a two and one-half year old child which had a typical "digestion-insufficiency" as described by Heubner.[3] The most recent experiments of Uffenheimer [4] seem to indicate that casein is present in the stools more frequently than was formerly thought, as it has been found in the salve-like skimmed milk stools.

Selter [5] described a picture of "intoxication" in which there is an excursion of temperature from 37° to 34° (*i. e.*, subnormal), slow pulse and superficial respiration. The color of the skin is bluish-gray. The urine contains no reducing substance. The stools are curdy and grayish-yellow, with a cheesy odor. The urine contains a kenotoxine, which, when injected into mice, causes a condition similar to that described in the babies. The disease is cured by small amounts of breast milk, or by carbohydrates, and is attributed to the proteins. Monrad [6] and Morse [7] do not believe with Finkelstein and his followers that casein is absolutely harmless, but think that it can cause dyspepsia.

Holt and Levene [8] found that large quantities of casein given by mouth could cause a rise in temperature. They observed a rise in temperature in five instances that continued until the food was changed, and then subsided to normal. Fever occurred only when their "synthetic food" contained six per cent of casein. There was

[1] Ibrahim: Monatschr. f. Kinderh., 1911, x, 55.
[2] Brennemann: Am. Jour. Dis. Children, 1911, i, 341.
[3] Heubner: Verhandl. d. Gesellsch. f. Kinderh. in Salzburg, 1909, xxvi, 169.
[4] Uffenheimer: Sitzung der München Gesellsch. f. Kinderh., 1911; München med. Wochenschr., 1911, 876.
[5] Selter: Deutsch. med. Wochenschr., 1908, 512.
[6] Monrad: Monatsschr. f. Kinderh., 1911, x, 244.
[7] Morse: New York Med. Jour., 1913, xcvii, 477.
[8] Holt and Levene: Med. Klin., 1913, ix, 258.

a retention of chlorides for three or four days preceding the rise in temperature. They call attention to the parallelism between this fever and that produced by Vaughan by the paraenteral injection of protein. Their food contained a large amount of salts, however, and it is possible that the fever may have been caused by them.

ANAPHYLAXIS

The connection between anaphylaxis and the disturbances caused by cow's milk has always been a field for speculation. Hamburger [1] believed that foreign protein ("artfremdes Eiweiss") was "an irritant to the especially sensitive cells of the infant's alimentary tract and that the necessity of breaking down the protein molecule to such simple substances that they could not be injurious after absorption threw an added burden on the digestion and one which was unnecessary with milk of the same species." Howland [2] has brought forward some evidence against this theory. Recent investigations, however, have added positive evidence. Moro and Bauer [3] found precipitines in the blood of marantic infants in a few instances. There is not much doubt that during the first weeks of life a foreign protein can pass through the intestinal wall. Schloss [4] and Berger [5] have given indirect, but suggestive evidence by differential counts of the blood, that when a foreign protein is introduced for the first time into the gastrointestinal canal of infants, there is a similar reaction in the body to that obtained in active sensitization and immunity of the body. These two pieces of work suggest that the sequence of sensitization and immunity takes place when any foreign protein is introduced into the intestinal canal. Lust [6] fed different forms of foreign protein to children with digestive disturbances and found by the precipitine reaction that egg albumen passed through the intestinal wall in nine of sixteen cases of acute and chronic nutritional disturbances, while ox serum passed through in only one of seventeen cases. Hahn [7] found that in five out of

[1] Hamburger: quoted by Howland,—Am. Jour. Dis. Children, 1913, v. 390.

[2] Howland: Am. Jour. Dis. Children, 1913, v. 390.

[3] Moro and Bauer: quoted by Howland,—Am. Jour. Dis. Children, 1913, v. 390.

[4] Schloss: Paper read at the Am. Assoc. for the Study and Adv. of Clinical Investigation, May 11, 1914.

[5] Berger: Paper read at the Thirty-fifth meeting of the New England Pediatric Society, held January 29, 1915.

[6] Lust: Jahrb. f. Kinderh., 1913, lxxvii, 383.

[7] Hahn: Jahrb. f. Kinderh., 1913, lxxvii, 405.

twenty-three infants with acute nutritional disturbances antitoxin passed from the intestine into the blood. Modigliani and Benini [1] found by means of the precipitine reaction that the blood of infants fed on cow's milk showing symptoms of gastrointestinal disturbances, was always positive for cow casein. Sick new-born babies gave a positive reaction, while older breast-fed babies were negative even when they were given a little cow's milk during an acute intestinal disturbance. No healthy infants gave positive reactions. Vaughan [2] calls attention to the fact that peptone and other products of decomposition of protein may cause symptoms of disease and that "sensitization may result from the absorption of undigested or partially digested proteins from the alimentary tract."

Differences in the Absorption of Human and Cow's Milk Nitrogen.—In most instances less nitrogen is taken in the food of naturally fed babies than in that of artificially-fed ones, but when approximately the same amounts of each are ingested there is less fecal nitrogen in the artificially-fed babies than in those fed naturally.[3] The nitrogen in the feces of both naturally and artificially-fed babies increases, other things being equal, with an increase of nitrogen in the food. There may, however, be considerable variations in the nitrogen excreted by the same child on the same food if the observation is continued over a long period of time, as is shown by the work of Cronheim and Müller.[4]

Starvation stools.—Experiments on animals and man have shown that during starvation there are only small amounts of nitrogen in the feces, that when a nitrogen-free food is given there is considerable increase in the fecal nitrogen [5] and that there may be more nitrogen in the stools on a nitrogen-free food than on one containing a large amount of nitrogen. It may be assumed, therefore, that the animal albumins are probably completely or almost entirely absorbed in health. It is evident also that the nitrogen in the feces comes principally from the intestinal secretions and the intestinal bacteria. Keller [6] found that a baby excreted 0.74 gm. nitrogen per day in one experiment and 0.097 gm. in another, while undergoing starvation.

[1] Modigliani and Benini: Policlinico, Rome, Dec. med. Section, 1914, No. 12, 533.

[2] Vaughan: Jour. Am. Med. Assoc., 1913, lxi, 1761.

[3] See Tables in Keller: Phosphor. und Stickstoff im Sauglingsorganismus. Arch. f. Kinderh., 1900, xxix, 1; and Orgler: Ueber Harnsaureausscheidung im Säuglingsalter. Jahrb. f. Kinderh., 1908, lxvii, 383.

[4] Cronheim and Müller: Biochem. Zeitschr., 1908, ix, 76.

[5] Rubner: Zeitschr. f. Biol., 1879, xv, 115, and others.

[6] Keller: Arch. f. Kinderh., 1900, xxix, 1.

It would be expected that when the amount of food is increased there would be an increased flow of digestive juices, but figures do not bear out this assumption. Vegetable nitrogen is digested and absorbed with greater difficulty than animal nitrogen. Wohlgemuth [1] found that he could cause an increased flow of pancreatic juices in a man with a pancreatic fistula by feeding carbohydrates and that protein caused a less profuse flow.

THE METABOLISM OF PROTEIN

Schlossmann and Murschhauser [2] investigated the fasting metabolism of infants. Their paper should be consulted in the original for the literature and the details of the investigations. They found that the nitrogen excretion in the urine during fasting depended upon the quality of the food ingested before fasting was commenced and that the greater the protein (nitrogen) content of the food, the greater was the excretion of nitrogen. For example, Baby 14:—

TABLE 13

Nitrogen content of urine per hour, per kilogram	Grams	Nitrogen content of urine per hour per kilogram	Grams
Feeding with human milk	0.00363	Modified cow's milk	0.0119
On first day of fast	0.00513	First day's fast	0.0160
On second day of fast	0.00686	Second day's fast	0.0151
On third day of fast	0.01083	Food again given	0.0080
On first day after fast	0.0068		
On second day after fast	0.0042		

When human milk had been used less body protein was broken down during starvation than when modified cow's milk was used. After eighteen hours of fasting the nitrogen in the urine represents the products of the katabolism of the body protein. The acetone bodies increase in the urine during fasting, and the evidence points to the absence of carbohydrate in the food as the cause.

When the amount of protein in the food is increased there is increased retention of nitrogen.[3] Babies, unlike adults, are able to retain nitrogen even when they are not receiving the required number of food calories. They may continue to do so even under the most discouraging circumstances.

In adults when the total carbohydrate of the food is replaced by

[1] Wohlgemuth: Berl. klin. Wochenschr., 1907, 47.
[2] Schlossmann and Murschhauser: Biochem. Zeitschr., 1913, lvi, 355.
[3] Meyer, L. F.: Biochem. Zeitschr., 1908, xii, 422.

fat of an equal caloric value there is a considerable albumen deficit.[1] If only a part of the carbohydrate is replaced by fat, the body will eventually return to a nitrogenous equilibrium. Orgler believes that in normal babies, however, the amount of fat in the food influences the nitrogen metabolism to only a slight degree. Increasing the fat in the food of babies that do not digest fat well may, on the other hand, result in a negative nitrogen balance. It is not known whether the action of the fat of human milk and of cow's milk is the same or not. In Courtney's cases [2] the nitrogen retention was higher in those babies which showed a very considerable gain in weight in the course of the experiment and were, therefore, in the stage of reconvalescence. Fat does not seem to have the property of sparing protein.

Carbohydrates, on the other hand, have a marked property of sparing nitrogen.[3] Cane and milk sugar have the same action as malt sugar. When they are added to the food there is usually an increase in the nitrogen retention. When carbohydrates are given in excess, they cause increased peristalsis, frequent stools and a considerable loss of nitrogen from the body.[4, 5]

The growing body requires protein from which to build up the body tissues, muscles, etc., while carbohydrates and fats are used as fuel. It is obvious, therefore, that more protein or nitrogen must be ingested than is excreted in order that the needs of the growing tissues may be supplied. The osseous system, in the same way, requires mineral salts for its growth, and more salts must be ingested in the food than are lost in the excreta. These salts which are retained in the body are used to build up new bone. When the baby is gaining weight and strength, there is a retention of both nitrogen and salts and when the baby is not gaining, there may be a loss of both of these bodies. When one is retained in the body the other is apt to be retained, and vice versa, as shown by Orgler's baby No. 9.[6]

The metabolism of breast-fed babies can be compared more easily than that of bottle-fed babies because the food, *i. e.*, breast milk is essentially the same in all cases, while that of artificially-fed babies differs a great deal. Orgler found that in general there is more nitrogen retained per kilogram of body weight in young

1 Landergreen: Skandin. Arch. f. Physiol., 1903, xiv, 112.

2 Courtney: Am. Jour. Dis. Children, 1911, i, 321.

3 Keller: Maltsuppe, eine Nahrung für magendarmranke Säuglings. Jena, 1903.

4 Orgler: Jahrb. f. Kinderh., 1908, lxvii, 383.

5 Talbot and Hill: Am. Jour. Dis. Children, 1914, viii, 218.

6 Meyer, L. F.: Ergebniss d. inn. Med. und Kinderh., 1908, i, 317.

babies than in older babies; that is, the retention decreases as the baby grows older.

Both the retention and the utilization of nitrogen must be taken into consideration when the various cases in literature are compared. Utilization represents the amount retained as compared with the amount in the food. The following table taken from Schwarz gives an idea of utilization:

TABLE 14

Age	*Up to 14 days*	*2–3 months*	*5 months*
Retention.........	0.351	0.153	0.048
Utilization........	78.3%	40.8%	23.1%

The foregoing table shows that the younger the baby is, the greater is the retention and utilization of nitrogen. This corresponds with clinical observations of growth, for the very young baby grows very rapidly and, therefore, retains and uses more nitrogen in building up new body tissues than the older baby which does not increase so rapidly in size. Under certain conditions of under-nourishment, an increase in the amount of nitrogen in the food results in an increased retention of nitrogen and improvement in the general condition of the baby. In other conditions an increase of the food nitrogen causes greater retention but not necessarily a gain in weight. There is no explanation of why this increase in the retention of nitrogen does not necessarily benefit the baby. Sick infants cannot retain as much nitrogen as well babies of the same age. Fife and Veeder [1] found that two cases of infantile atrophy had a greater retention of nitrogen than normal babies of the "same age and weight." The question may be raised, however, as to whether the babies examined could have been atrophic if they were of the same weight as normal babies of the same age. When the amount of carbohydrate in the food was increased there was increased retention of nitrogen but the nitrogen retention was not influenced by the amount of fat in the food.

Czerny and Steinitz [2] have collected the figures of the nitrogen metabolism of infants with disturbances of digestion and found that the absorption was approximately normal except during diarrhea. Although the evidence all seems to show that there is a

[1] Fife and Veeder: Am. Jour. Dis. Children, 1911, ii, 19.

[2] Czerny and Steinitz: Stoffwechselpathologie des Kindes, Noorden's Handbuch d. Path. d. Stoffwechsels, II, 391.

retention of nitrogen in practically all instances, yet this evidence is not sufficient to warrant its acceptance without reserve. Gamble [1] has shown that in alkaline stools twenty per cent of the nitrogen can be lost in the form of ammonia during the process of drying. This loss of nitrogen has not been taken into consideration in the metabolism experiments of other writers and might be sufficient to result in a negative balance of nitrogen in some of the instances in which the balance has been reported positive.

[1] Gamble: Am. Jour. Dis. of Children, 1915, ix, 519.

CHAPTER V

THE METABOLISM OF THE MINERAL SALTS

The metabolism of the mineral salts was first investigated by Liebig [1] in 1840. Very little information of value in relation to the problems of infant feeding and metabolism has been added since then, however, until recent years. Even such information as we now have is being continually modified or disproved by chemists, who find that the methods which were employed in obtaining the figures gave erroneous results. Summaries of the present knowledge of the metabolism of the mineral salts are given by Albu-Neuberg,[2] L. F. Meyer,[3] Hoobler,[4] and Tobler and Bessau.[5]

The body of the new-born infant is relatively richer in water and fat and poorer in nitrogen and ash than the body of the adult. The body of the fetus contains a very large proportion of water, the proportion diminishing as the fetus grows older. The composition of the ash of the new-born infant is according to Soldner [6] as follows:

In one hundred parts of the new-born infant there is K_2O, 7.06; Na_2O, 7.67; CaO, 38.08; MgO 1.43; M_2O_3, 0.11; F_2O_3, 0.83; $Mn_3 O_4$, 0.03; $S_2 O_5$, 37.66; So_3, 2.02; Cl, 6.61; SiO_2, 0.06; Co_2, 0.53.

Human milk contains, with the exception of iron, much less of the mineral salts than cow's milk. More of the salts in human milk are in organic combination than in cow's milk and for that reason are supposed to be utilized more easily. Soldner [7] found that the sodium, potassium, and chlorine content of human milk decreased as lactation progressed, while the bone-forming constituents, calcium, magnesium and phosphorus, remained fairly constant.

[1] Liebig: Chemie in ihre anwendungs fur Agrikultur und Phys. 1876.
[2] Albu-Neuberg: Mineralstoffwechsel, Berlin, 1906.
[3] Meyer, L. F.; Ergebnisse d. inn. Med. u. Kinderh., 1908, i, 317.
[4] Hoobler: Am. Jour. Dis. Children, 1911, ii, 107.
[5] Tobler and Bessau: Allgemeine Pathologische Physiologie der Ernährung und des Stoffwechsels im Kindesalter, Wiesbaden.
[6] Soldner: quoted in Pfaundler and Schlossmann: The Diseases of Children, Phila. and London, 1908, i, 364.
[7] Soldner: *loc. cit.*

The mineral salts play a very complicated part in digestion, because they are not only absorbed by the intestines, but also may be re-excreted into the digestive canal. There are also complicated reactions which take place between the organic and inorganic food components.

The digestive juices contain salts. Bile contains from $\frac{1}{2}$ to 1% of ash, which is especially rich in sodium and chlorides.[1] It also contains smaller amounts of potassium, calcium, and magnesium in combination with phosphoric acid. The pancreatic juices contain $\frac{1}{2}$% of ash, the greater part of which is in the form of sodium carbonate. The intestinal secretions are also rich in carbonates.

Metabolism of Ash.—Cow's milk contains much more ash than human milk, and, therefore, much more salt is given to the infant taking an artificial food prepared with cow's milk than it requires. The breast-fed infant [2] absorbs about 80% of the ash in the food and retains between 40% and 50% while the artificially-fed infant absorbs from 43% to 78% and retains from 43% [3] to none at all or may even loose ash from the body.[4] Hoobler [3] found, in his experiments, that the retention of mineral salts as compared with the retention of nitrogen was relatively poor. The retention was poorest when the food contained but little fat, was better when it contained a medium amount of fat, and was best when it contained a large amount of fat (5.4%). Talbot and Hill [4] kept the fat and protein in the food approximately the same in seven periods, and found that when the carbohydrate was increased beyond the limit of tolerance and diarrhea resulted there was a loss of ash from the body. The increased excretion of ash was through the feces.

Metabolism of Calcium.—The metabolism of calcium is described in detail in the chapter on rickets. For that reason it is unnecessary to speak of it here except to say that some investigators criticise the methods which were used to quantitate the amount of calcium and show that they are inaccurate.

Metabolism of Iron.—The amount of iron in both cow's milk and human milk is small and is insufficient for the needs of the growing infant. Nature has deposited enough iron in the liver [5] of the new-born infant, however, to last it until it can digest

[1] Tobler: *loc. cit.*
[2] Blauberg: Zeitschr. f. Biol., 1900, xl, 1.
[3] Hoobler: Am. Jour. Dis. Children, 1911, ii, 107.
[4] Talbot and Hill: Am. Jour. Dis. Children, 1914, viii, 218.
[5] Bunge: Zeitschr. f. physiol. Chemie, 1889, xiii, 399.

foods which contain sufficient amounts of iron. The iron in human milk is apparently more easily retained than that in the milk of animals. The following table of Krasnorgorski [1] illustrates this point.

TABLE 15

IRON METABOLISM OF THE SAME BABY IN TWO PERIODS

Author	*Food*	*Iron in food*	*Feces*	*Urine*	*Absorbed mg.*	*Absorbed %*	*Retained mg.*	*Retained %*
Krasnorgorski	Human milk	7.05 mg.	0.84 mg.	0.55 mg.	6.21	88.09	5.66	80.28
Krasnorgorski	Goat's milk	3.44 "	2.59 "	0.09 "	0.85	24.71	0.76	22.09

Metabolism of Magnesium.—The absorption and retention of magnesium are higher in the breast-fed than in the artificially-fed infant. Hoobler [1] found that when an infant was taking an artificial food the retention was better when there was a low percentage of fat in the food than when there was a high percentage of fat.

Metabolism of Phosphorus.—One litre of human milk contains from 0.31 to 0.45 grams of phosphorus and one litre of cow's milk about 1.81 grams. Three-quarters of the phosphorus in human milk is in organic combination, while only one-quarter of the phosphorus in cow's milk is in organic combination; 41.5% of the total phosphorus in human milk is in the form of nucleon phosphorus and only 6% in cow's milk.

According to Blauberg [2] 89.2% of the phosphorus in human milk and 53.2% of that in cow's milk is absorbed. Hoobler [3] found that more was absorbed when the food contained a high per cent. than when it contained a low per cent. of fat. Knox and Tracy [4] confirmed the work of Keller showing that the bottle-fed baby excretes much more phosphorus in the urine than the breast-fed infant. The latter excretes very little or none. According to L. F. Meyer,[5] the retention of phosphorus is less in the artificially-fed than in the breast-fed infant, the former retaining about 30% of the intake and the latter 69.13%.

[1] Quoted by L. F. Meyer: Ergeb. d. inn. Med. u. Kinderh., 1908, i, 327.

[2] Blauberg: see Hoobler, *loc. cit.*

[3] Hoobler: *loc. cit.*

[4] Knox and Tracy: Am. Jour. Dis. Children, 1914, vii, 409.

[5] Meyer, L. F.: Ergeb. d. inn. Med. u. Kinderh., 1908, i, 317.

Metabolism of Sodium and Potassium.—There is more potassium than sodium in milk. Human milk contains less sodium and potassium than cow's milk. The absorption of these salts is good for both milks. The retention is better on human milk than on cow's milk, being 67% for sodium and 74% for potassium on human milk, while on cow's milk it is 15.27% for sodium and 16.12% for potassium. Both salts are eliminated in both the urine and feces, from 15% to 25% of the intake being eliminated in the feces.[1]

Metabolism of Chlorides.—Very little is known about the metabolism of the chlorides.

Metabolism of Sulphur.—Hoobler finds that the sulphur of both human and cow's milk is well absorbed, the absorption taking place principally in the small intestine. Sulphur is eliminated almost entirely through the urine, but a small part is eliminated into the large intestine. The retention of sulphur is better when human milk is taken than when cow's milk is taken.

The Influence of the Various Food Components on the Metabolism of the Mineral Salts.—There are very few investigations which throw any light on the influence of the individual food components on the metabolism of the mineral salts.

Howland [2] found that carbohydrates increased the retention of calcium.

L. F. Meyer found that the addition of casein to the food diminished the absorption of all the mineral salts.

Steinitz [3] Rothberg [4] and Birk [5] found that as the fat in the food was increased the loss of mineral salts in the feces was also increased. This loss was especially of calcium and magnesium and sometimes resulted in a negative balance. Courtney [6] on the other hand, did not find that fat had any marked influence on the retention of ash in infants with chronic indigestion.

L. F. Meyer [7] found that infants with "Bilanzstorung" lost from 34% to 60% of the ash in the food through the feces as compared with from 20% to 25% in normal cases. In the stage of intoxication he found that more sodium, potassium, and chloride were

[1] Hoobler: Am. Jour. Dis. Children, 1911, ii, 107. See table and references.

[2] Howland (not yet published). Read before the Am. Ped. Soc'y, Wash., 1913.

[3] Steinitz: Monatsschr. f. Kinderh., 1902–3, i, 225; Jahrb. f. Kinderh. 1903, lvii, 689.

[4] Rothberg: Jahrb. f. Kinderh., 1907, lxvi, 69.

[5] Birk: Jahrb. f. Kinderh., 1907, lxvi, 300.

[6] Courtney: Am. Jour. Dis. Children, 1911, i, 321.

[7] Meyer, L. F.: Jahrb. f. Kinderh., 1910, lxxi, 379.

lost in the feces but that there could still be a retention of calcium and phosphorus. There is always a loss of ash from the body [1] in acute diarrhea, although even under these circumstances a retention of calcium is possible. The reverse is apparently true when "soap stools" are passed.

[1] Tobler and Bessau: *loc. cit.*

CHAPTER VI

THE ENERGY METABOLISM OF INFANTS

The earliest investigation of the gaseous metabolism of infancy is that reported by J. Forster, of Munich in 1877.[1] He found with the large Pettenkofer-Voit respiration chamber that the infant produces much more carbon dioxid per unit of weight than does the adult. In France Richet, Langlois, Variot and Saint-Albin, Bonniot, Variot and Lavaille[2] and C. Weiss published a series of investigations on the metabolism of new-born infants and atrophic infants between the years 1885 and 1912. In 1898 the classical monograph of Rubner and Heubner[3] appeared. They studied the average daily requirement of food of a normal infant and in the following year[4] of an atrophic infant. They point out the fact that in human beings the carbon dioxid excretion is proportional to the body surface, whatever their size.

In 1908 the first of a series of investigations by Schlossmann and Murschhauser[5] appeared, and this, with subsequent articles, the last of which was published in 1914[6] have added much to our knowledge of the metabolism of infancy. These authors emphasize the influence of muscular activity on metabolism and they studied the basal metabolism (Grundumsatz) during complete repose for the purpose of comparing the metabolism in health and disease. They conclude that slight changes in the temperature of the surrounding air are without influence on the metabolism. Their investigations led them to study also the fasting metabolism in order to eliminate the influence of work done during digestion.

Other investigators, whose names should be mentioned, are Mensi, Poppi, Scherer[7] Babak, and Hasselbach, Barhdt, Birk, Edelstein and Niemann.

[1] Forster: Amtl. Ber. d. 50 Versammlung deutsch. Naturforscher u. Aerzte in München, Munich, 1877, 355.

[2] For synopsis of literature see Benedict and Talbot: Gaseous Metabolism of Infants, Carnegie Institution of Washington, Publication 201.

[3] Rubner and Heubner: Zeitschr. f. Biol., 1898, xxxvi, 1.

[4] Rubner and Heubner: Zeitschr. f. Biol., 1899, xxxviii, 315.

[5] Schlossmann and Murschhauser: Biochem. Zeitschr., 1908, xiv, 385.

[6] Schlossmann and Murschhauser: Biochem. Zeitschr., 1914, lviii, 483.

[7] See Benedict and Talbot: Am. Jour. Dis. Children, 1914, viii, 1.

In America, Carpenter and Murlin [1] studied the energy metabolism of pregnant women before and after the birth of the child.

Howland [2] studied the direct calorimetry and compared it with the heat calculated from the carbon dioxid excretion and oxygen consumption. He found that the heat-production as directly measured and as indirectly computed was strikingly close, the greatest difference being two per cent. Benedict and Talbot [3] reported from the Nutrition Laboratory of the Carnegie Institution of Washington in 1914, the results of three years' investigations with a respiratory chamber on about eighty babies, of which sixty-one were reported in detail. Murlin and Hoobler [4] reported the results of their investigations with a respiratory chamber on a few infants in 1915.

Methods of Computing the Energy Metabolism.—There are several ways of computing the energy metabolism of infants: first, by measuring the heat lost by an infant in a calorimeter; second, by computing the heat production by collecting the carbon dioxid excreted and measuring the oxygen consumed by an infant in a respiratory chamber. Zuntz [5] has computed the calorific value of oxygen with different respiratory quotients and these figures may be considered to-day as the best data we have for the computation of the energy output from the measurement of the gaseous exchange. Knowing the respiratory quotient the calculation of the calorific value of carbon dioxid is a simple one. (Benedict and Talbot, Carnegie Institution of Washington, Publication 201, Table fifteen, page twenty-nine, gives the calorific equivalents of carbon dioxid.)

It is, therefore, possible to determine how many calories are used during a given period when the carbon dioxid and the respiratory quotient are known; thirdly, the energy metabolism has been computed by investigators who have measured the fat, carbohydrate and protein intake and the loss of fat, carbon and nitrogen in the excreta; and finally, the energy metabolism is roughly computed by clinicians who know the approximate or theoretical composition of the elements in the food. The last method is of little or no

[1] Carpenter and Murlin: Arch. Internal Med., 1911, vii, 184.

[2] Trans. Fifteenth Internat. Cong. Hyg. and Demog., 1911, ii, 438.

[3] Benedict and Talbot: Carnegie Institution of Washington, Publication 201; and Am. Jour. Dis. Children, 1914, viii, 1.

[4] Murlin and Hoobler: Am. Jour. Dis. Children, 1915, ix, 81. See also Bailey and Murlin, Am. Jour. of Obstetrics and Dis. of Women and Children, 1915, lxxi, 526, for the Metabolism of New-born Babies.

[5] Zuntz, quoted by Benedict and Talbot: Carnegie Publication of Washington, No. 201, 1914.

scientific value since the composition of the food varies even when the greatest precautions are taken to keep it uniform. It is of value only to the clinician in his practical work and may give false information.

Howland, working in Professor Lusk's Laboratory at Cornell University Medical School, showed in a very brilliant way that the output of heat when measured directly and when computed from the carbon dioxid and oxygen, coincided very closely. The greatest difference was two per cent. Other investigations, in which the heat was computed from the carbon dioxid and oxygen, are, therefore, within very small limits of error.

The Effect of Muscular Exercise on Metabolism.—Schlossmann appreciated the fact that muscular exercise caused a marked increase in the heat production of an infant. Howland found a difference of 17.6% and 39% in the heat production between periods of quiet sleep and active struggling and crying, while Murlin and Hoobler found that hard crying may increase the metabolism as much as 40%. Benedict and Talbot found that an increase of 60% was common and that there could be an increase of 100% (as in the case D Q Dec. 22 [1]) from quiet sleep to active exercise. It is obvious, therefore, that a comparison of the metabolism of an active healthy infant with that of a quiet sick infant is of no value, because in one the effect of muscular activity is added to the basal metabolism and in the other it is not. The basal metabolism, that is, the metabolism during complete muscular repose, should be always used when health and disease are compared.

The Effect of Fasting on the Metabolism.—There is evidence which seems to show that the metabolism of infants after taking food is always higher than it is in the same infant while fasting.[2] Howland,[3] in commenting on one of his experiments says: "This experiment, so far as one can do so, brings additional proof to the view that insufficient food reduces the carbon dioxid excretion, but that after eighteen hours, a fasting metabolism is not reached with infants, as shown by the normal heat production and by the respiratory quotient of 0.81." Schlossmann and Murschhauser [2] found that after eighteen hours of fasting acetone soon appears in the urine in considerable quantities. The question can be raised, therefore, whether an infant, which has been starved more

[1] Benedict and Talbot: Carnegie Institution of Washington, Pub. 201, p. 97.

[2] Schlossmann and Murschhauser: See Murschhauser, Boston Med. and Surg. Jour., 1914, clxxi, 185.

[3] Howland: Tr. Fifteenth Internat. Cong. Hyg. and Demog., 1912, ii, 438.

than twenty-four hours and whose urine contains considerable quantities of acetone, can be considered normal. Benedict and Talbot[1] studied the fasting metabolism of several infants at periods from three to twenty-four hours after food had been given. They found that the respiratory quotient was markedly lowered after eighteen hours of fasting. The figures of heat production obtained were inconsistent, because it was almost impossible to obtain half hour periods for study in which the fasting infant was in complete muscular repose. If the metabolism is lower after eighteen or twenty-four hours' fast than it is directly after taking food, it must be only slightly diminished. Further investigations must be carried on to decide at which point the metabolism of a fasting infant changes from a physiological condition into a pathological condition. For this reason recent investigations have been confined almost entirely to measuring the metabolism directly after food has been given.

Comparison of Body Surface and Metabolism.—For many years writers on metabolism have been wont to emphasize the significance of the relationship supposed to exist between the metabolism and the body surface rather than that between the metabolism and the body weight. The idea that there is an intimate relationship between body surface and heat production was first brought out by Bergmann[2] in 1847. The theory lay dormant for many years, but was finally resuscitated and put forth in a brilliant and highly stimulating manner by Rubner[3] in 1883, together with experimental evidence. Based fundamentally on Newton's law of cooling, it received great attention from practically all workers in physiology. The startling evidence which was brought forward to demonstrate that the heat production per square meter of body surface was about 1,000 calories for practically all species of animals lent further support to this hypothesis.

The researches of Benedict and Talbot,[4] confirmed by Murlin and Hoobler,[5] show that such conclusions are not warranted since the relation between the basal metabolism of infants and the body surface is not uniform. The following chart illustrates this point:

[1] Benedict and Talbot: Carnegie Institution of Wash., Pub. 201.

[2] Bergmann and Leuckart: Anatomisch-physiol. Uebersicht des Thierreichs, Stuttgart, 1852, 272; Bergmann: Wärmeökonomie der Thiere, Göttingen, 1848, 9.

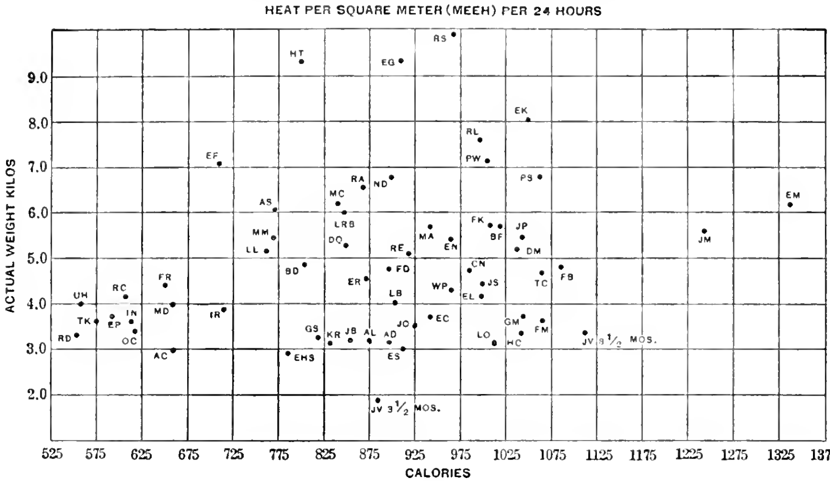
[3] Rubner: Ztschr. f. Biol., 1883, xix, 545.

[4] Benedict and Talbot: Am. Jour. Dis. Children, 1914, viii, 1.

[5] Murlin and Hoobler: Am. Jour. Dis. Children, 1915, ix, 81.

CHART I (Benedict and Talbot)[1]

Chart showing actual body weight of infants and heat production per square meter of body-surface (Meeh formula) per twenty-four hours



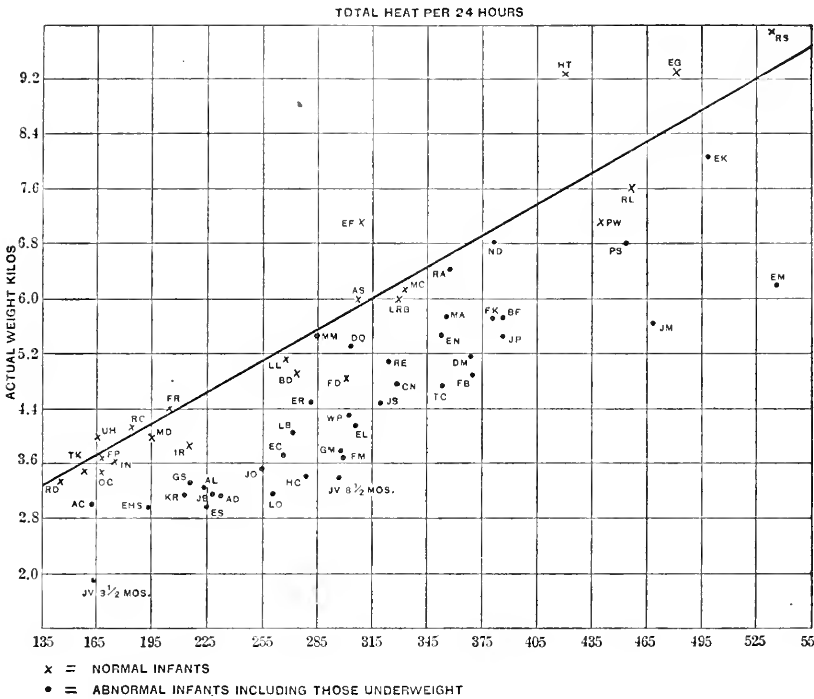
This chart shows that the basal metabolism per square meter of body surface varies over one hundred per cent. when new-born infants, viz., those lying to the left of the line marked 675 calories are included. They[1] conclude,—"that our evidence points strongly and conclusively to the fact that the active mass of protoplasmic tissue determines the fundamental metabolism. The absence as yet of a direct mathematical measure of the proportion of active protoplasmic tissue does not, we believe, in any wise affect the convincing nature of our evidence."

The total basal metabolism of an infant increases with its age and weight, as would be expected. On the following chart, taken from the paper by Benedict and Talbot,[1] the normal infants are indicated by crosses and the abnormal infants, including those that are under-weight, are indicated by dots. A hypothetical curve has been constructed for the normals that shows the tendency of the metabolism to increase with the weights of the infant. In general, those infants which weigh more than the average for the age lie above the curve while those which weigh less than the average fall below the curve.

[1] Benedict and Talbot: Am. Jour. Dis. Children, 1914, viii, 1.

CHART II

Chart showing the actual body weight of infants and the total heat production per twenty-four hours



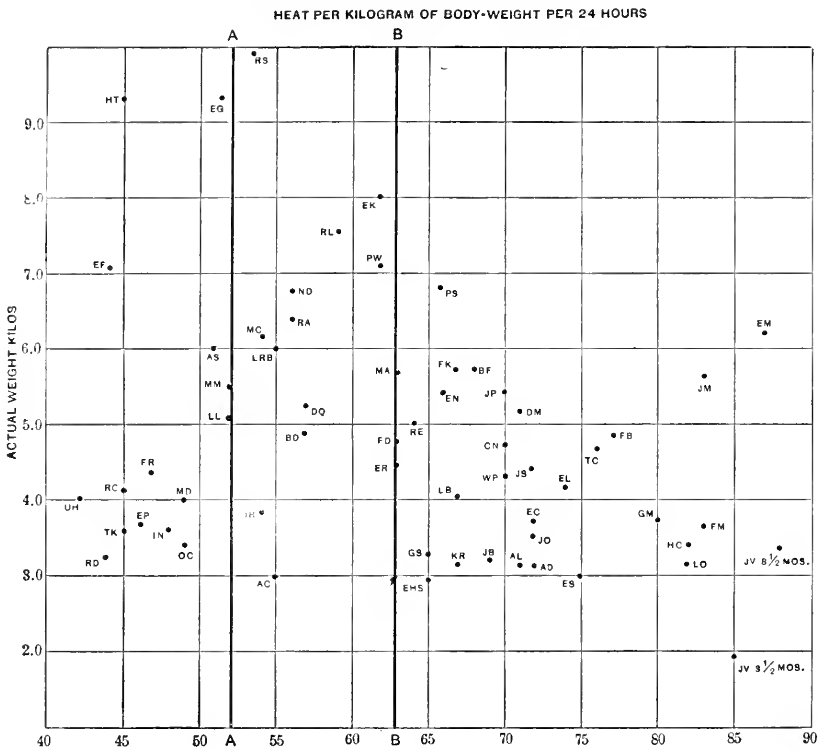
The comparison of the basal heat production per kilogram of body weight is of more practical interest to the clinician.

Chart III on the next page is taken from the paper of Benedict and Talbot.

In general, the babies weighing the average for the age and in all respects normal fall between the lines marked A and B or, roughly their basal metabolism is between 52 and 63 calories per kilogram of body weight. The normal infants, other than new-borns, that have a great deal of fat on their body in proportion to their musculature, have a basal metabolism of between forty and a little more than fifty calories per kilogram of body weight. New-born infants are included in this class. Most of the infants that are under-weight have a basal metabolism of more than sixty-five calories per kilogram of body weight and, in general, the more they are underweight, the greater is the basal metabolism. This chart shows

CHART III

Chart showing the actual body weight of infants and the heat production per kilogram per twenty-four hours



that the basal metabolism per kilogram of body weight may vary one hundred per cent. in different infants.

The Respiratory Quotient.—The respiratory quotient is the ratio between the volume of carbon dioxid expired and the volume of oxygen inspired during the same time, viz., $\frac{\text{vol. } CO_2}{\text{vol. } O_2} = \text{R. Q.}$ When carbohydrates are burned the respiratory quotient is unity, that is, for every hundred volumes of carbon dioxid excreted a hundred volumes of oxygen are absorbed. (The respiratory quotient for carbohydrates is 1.00.) The respiratory quotient for fat is 0.713 and for protein 0.801. The respiratory quotient, when carefully determined, throws considerable light on the character of the materials burned in the body.

Caloric Values.—Rubner's "standard values" have been widely used throughout the world in determining the average fuel value of a mixed diet. They are:

1 gram of protein	4.1 calories (large)
1 gram of fat	9.3 calories (large)
1 gram of carbohydrate	4.1 calories (large)

The heats of combustion of the carbohydrates are as follows:

	Stohmann [1]	Emery and Benedict [2]
Dextrose	3.692	3.739
Lactose	3.877	3.737
Saccharose	3.959	3.957
Starch	4.116	

Since the carbohydrates used in infant feeding are usually sugars rather than starch, the caloric value of the carbohydrate would be more accurate if a lower factor were used, for instance, 3.7 for lactose.

Computed Metabolism.[3]—The energy quotient is the term applied by Heubner [4] to the number of large calories per kilogram of body weight per day that are necessary for growth. The metabolism of a large number of infants has been computed when the amount of fat, carbohydrate, or protein in the food was known, or in which averages of the various analyses of milk were taken. It has been shown by many investigators that the percentage composition of human milk can vary within very wide limits, and obviously there must be a corresponding fluctuation in its caloric value. For this reason many of the computed energy quotients, based upon the average composition of human milk, are criticised. Heubner [5] concluded that a breast-fed infant did not gain satisfactorily on human milk during the first three months when the energy quotient fell below one hundred calories, and that when the energy quotient fell below seventy calories there must be a loss of weight. Schlossman [6] on the other hand found the best gain on an energy quotient of one hundred and ten calories. Premature infants and artificially-fed infants, according to Heub-

[1] Quoted by Lusk: The Science of Nutrition, Phila. and London, 1909, 41.

[2] Emery and Benedict: Am. Jour. Phys., 1911, xxviii, 301. Later they showed even a greater difference in the heat of combustion of lactose.

[3] An excellent review of the Continental work may be found in Frank: Energiequotient und Temperatur im Sauglingsalter. Inaug. Dissert. München, 1913.

[4] Heubner: Kinderh., 3 auflage, Leipzig, 1911, vol. I.

[5] Heubner: Jahrb. f. Kinderh., 1910, lxxii, 121.

[6] Schlossmann: Arch. f. Kinderh., 1902, xxxiii, 338.

ner, should have an energy quotient of not less than one hundred and twenty calories during the first three months of life. Feer [1] found that the energy quotient of Baby Marianne, the composition of whose food was known, during the thirty-third to the forty-sixth week of life was between eighty-six and one hundred and four calories. He believes that the reason artificially-fed infants require more calories than the breast-fed is that the work of digestion is greater in the former than in the latter. Cramer [2] studied the energy quotient of infants during the first nine days of life, and found a gain of from fifty to sixty grams with an energy quotient of less than fifty calories. Gaus [3] confirmed these findings and it was concluded that there was a special metabolism for infants during the first two weeks of life.

Siegert [4] concluded that it was possible for the breast-fed infant to gain on eighty calories per kilogram of body weight during the first three months of life. Czerny and Keller [5] considered Heubner's figures too high and report an infant of average weight (Machill) which gained regularly on an average of seventy calories per kilogram of body weight. A daily examination of the milk was not made. Bundin [6] fed a number of infants on mixtures of cow's milk which gave an energy quotient of seventy calories. These infants were of the average or of less than the average weight and gained weight consistently. Oppenheimer [7] gave an energy quotient of one hundred and eleven calories to a normally developed infant and as high as one hundred and forty-two calories to an infant which had previously been underfed. Beck, in 1904,[8] collected the literature up to date and gives the following figures as an average energy quotient for breast-fed infants:

1–12 weeks	107 calories
13–24 weeks	91 calories
25–36 weeks	83 calories
37–44 weeks	69 calories

He concluded that artificially-fed and premature infants required an energy quotient of from one hundred and twenty to one

[1] Feer: Lehrbuch der Kinderh., 2nd Ed., 1912.
[2] Cramer: Münch. med. Wochenschr., 1903, 2, L, 1153.
[3] Gaus: Jahrb. f. Kinderh., 1902, N. F. lv, 129.
[4] Siegert: Versamml. d. Gesellsch., f. Kinderh., Stuttgart, 1906.
[5] Czerny and Keller: Des Kindes Ernährung, Ernährungsstörungen, und Erhährungstherapie, Leipzig and Wien, 1906, vol. i, 396.
[6] Bundin: See Czerny and Keller, p. 404.
[7] Oppenheimer: Arch. f. Kinderh., 1909, L. 355.
[8] Beck: Monatsschr. f. Kinderh., 1904–05, iii, 206.

hundred and forty calories. Ladd[1] gave an energy quotient which varies between ninety-three and one hundred and fifty-nine calories. Dennett[2] concluded that the average normal baby will do well on from one hundred and ten to one hundred and twenty calories per kilogram and that very emaciated babies require from one hundred and sixty to one hundred and seventy calories, while those who are only moderately emaciated require from one hundred and thirty to one hundred and fifty calories. Finally, Finkelstein,[3] Gittings,[4] and Mayerhofer and Roth[5] drew attention to the fact that infants who were under-weight required more calories than well-developed infants and advanced the suggestion that they require as many calories as they would need if they had developed in the normal manner.

The figures just given as to the clinical status of the caloric requirements of different infants show what a difference of opinion there is among the various authorities. There can be little doubt that in the main they are all correct, if one bears in mind the possibility of error in such rough calculations of the energy metabolism of infants. Unfortunately, the accurate measurement of the energy metabolism in the calorimeter or by the respiratory exchange is only for shorter or longer periods of the twenty-four hour day and does not give exact measurements of the twenty-four hour metabolism. It is necessary, therefore, to depend upon the knowledge of the basal metabolism of a large number of infants and to attempt to correlate this with the results of clinical experience.

Summary.—The basal metabolism of an infant is the metabolism determined after the taking of food, with the infant in complete muscular repose. Comparison of infants in different states of nutrition shows that roughly the normal infant, not the newborn, of the average weight for its age has a basal metabolism of between fifty and sixty-five calories per kilogram of body weight, irrespective of age. This is the lowest amount of energy on which a baby can maintain its body functions. The habits of healthy infants vary with the individual. One is phlegmatic and sleeps most of the day and night, while another is moving, kicking or crying during most of its waking hours. It has been shown that

[1] Ladd: Archives of Pediatrics, 1908, xxv, 178.

[2] Dennett: Trans. Section on Dis. of Children, Amer. Med. Asso., 1912, 186.

[3] Finkelstein: Lehrbuch der Sauglingskrankheiten i, 54.

[4] Gittings: Am. Pediatric Soc., Stockbridge, 1914, Reported in Jour. A. M. A., 1914, lxiii, 55.

[5] Mayerhofer and Roth: Zeitschr. f. Kinderh., 1914, xi, 117.

the metabolism may be increased from forty to one hundred per cent above the basal metabolism by the change from complete muscular repose to active exercise. If forty per cent is added to the basal metabolism of fifty calories per kilogram, the result will be an energy quotient of seventy calories. It seems probable, therefore, that the infants studied by Czerny, Budin and their followers were placid infants who conserved their energy for development. If one hundred per cent is added to the basal metabolism, the energy quotient is between one hundred and one hundred and thirty calories. Such infants must either be very active to use up all this "extra steam" or else they must lose undigested food or unabsorbed energy through the stools, or they must gain weight rapidly. It is probable, therefore, that Heubner and his followers dealt with more active infants than did the Czerny school. The concensus of opinion seems to be that breast-fed infants require less energy than the artificially-fed, because less energy is required to make the food available for the body. This may be the sole explanation, or it may be that the difference in their requirements is due to the fact that the breast-fed infant is on the average a quieter infant and that it sleeps more than the artificially-fed infant.

Babies that weigh more than the average weight for their age and new-born infants have usually a basal metabolism of between forty and fifty-two calories per kilogram of body weight. Both the new-born and fat infants are quieter than infants which have developed their muscles and as a result the energy required for muscular work, which must be added to their basal energy metabolism, is less than it is in active, crying infants. The large fat babies which weigh more than the average will, therefore, gain more weight on a low energy quotient than babies of average weight. The new-born infant falls into this class as it has a relatively large proportion of fat and a small proportion of muscle.

Moderately emaciated or atrophic infants have a higher basal metabolism than do the babies of average weight. It varies between sixty-three and eighty-seven calories per kilogram of body weight. When the energy required for muscular work is added to this, the energy quotient is the result. It must be remembered, however, that infants of this type that have many loose undigested stools may lose twenty per cent [1] or more of the energy of the food. If the infant is very weak and quiet, a small increase in the number of calories above the basal requirements will be sufficient to enable it to gain in weight. If, on the other hand, it is crying from morn-

[1] Benedict and Talbot: Am. Jour. Dis. Children, 1914, viii, 1.

ing to night because of either hunger or discomfort, a very much greater percentage of calories must be added to the basal requirements in order that it may grow. There also can be little doubt that in weak babies energy, which would otherwise be used to keep the baby warm, can be conserved by increasing the temperature of the infant's surroundings. The infant that is under-weight requires, therefore, somewhere between one hundred and thirty and one hundred and sixty calories per kilogram of body weight.

CHAPTER VII

BACTERIOLOGY OF THE GASTROINTESTINAL CANAL[1]

BACTERIOLOGY OF THE MOUTH

The infant's mouth is sterile before birth, but becomes infected from the mother's vagina during birth,[2] or from the air soon after birth.[3] The variety of organisms present at this time is relatively small, but as soon as the infant commences to take food the flora becomes more complicated. The number of bacteria does not, however, increase materially. When the infant takes breast milk, there is an increase in the variety of the organisms, and pathological bacteria even may be found in the mouths of healthy babies.[4] Because of the fact that even the purest cow's milk contains more bacteria than human milk it is reasonable to expect that the mouths of babies fed on the bottle will contain a greater variety of bacteria than those fed at the breast and that the dirtier the milk the greater will be the variety of the organisms. There are, however, no data as to whether this is true or not. After the eruption of teeth, *i. e.*, after the infant is six months old, the number and variety of the bacteria increase [5] and certain microörganisms, such as the Leptothrix,[6] and Fusiform bacteria,[7] which are apparently only able to obtain a foothold in the mouth when teeth are present,[8] appear.

It is an open question as to how important a part the bacteria of

[1] G. Bessau in Tobler, Allegemeine Pathologische Physiologie der Ernährung und des Stoffwechsels im Kindesalter, Wiesbaden, 1914, has been freely used in this chapter and many of the statements have been taken directly from it. It may be consulted by those who wish to go into the subject more deeply.

[2] Kneise: Sittler quoted by Tobler.

[3] Campo: La Pediatria, 1899, vii, 229.

[4] Doernberger: Jahrb. f. Kinderh., 1893, xxxv, 395; Herzberg: Deutch. med. Woch., 1903, xxix, 17.

[5] Noblécourt and Vicaris: Arch. gen. de Med., 1905, 2, 3201, ref. Monatsschr. f. Kinderh., 1905–6, iv, 640.

[6] Oshima: Arch. f. Kinderh., 1907, xlv, 21.

[7] Uffenheimer: Münch. med. Woch., 1904, 1198, 1253; Ergebnisse d. inn. Med. u. Kinderh., 1908, ii, 304.

[8] For a more detailed account of the flora of the mouth E. Kuster in Kolle Wasserman's Handbuch, II ed., Jena, 1913, vi, 435, may be consulted.

the mouth play in the digestion processes in the stomach. It is conceivable that these bacteria, especially when there is dental caries, may do harm. It has not been proven, however, that they do.

BACTERIOLOGY OF THE STOMACH

The same influences which modify the bacterial flora of the mouth modify that of the stomach. Under physiological conditions the bacteria in the stomach play an unimportant rôle. A description of the individual kinds may be found in the works of Escherich [1] who was a pioneer in this field of investigation. The smallest numbers are found in the stomachs of the breast-fed,[2] and they remain relatively scarce as long as the digestion is normal. When there is indigestion, there is an increase in their numbers. The greatest numbers are found in cholera infantum.[3]

Bactericidal Powers of the Stomach.—Free hydrochloric acid is able to destroy bacteria in the stomach.[4] There is no doubt that it is strongly attracted by the proteins of the food and quickly combines with them, thus becoming inert. Furthermore, the casein in the milk is rapidly coagulated into curds. The disinfecting action of the hydrochloric acid can only be effective on the surface of the curds, and the large numbers of bacteria which are present in the interior of the curds are not reached by it.[5] The number of bacteria in the stomach apparently depends also on the activity of the gastric motility, for the quicker the stomach is emptied, the fewer are the bacteria which it contains. The converse is also true.

Lactic acid fermentation does not seem to play as important a part in the stomach of the infant as it does in that of the adult in which it occurs only when hydrochloric acid is absent. Lactic acid is seldom or never found in the stomach of the breast-fed, but is frequently found in small amounts in the stomachs of infants fed on cow's milk.[5]

Butyric acid fermentation is more common,[6] and has been found to occur in the stomachs of atrophic infants in which the ex-

[1] Escherich: Die Darmbakterien des Sauglings, Stuttgart, 1886.

[2] Van Puteren: Ref. Zeitschr. f. mikroskopie, 1888, v, 539.

[3] Seiffert: Jahrb. f. Kinderh., 1891, xxxii, 392.

[4] Hamburger: Ueber die Wirkung des Magensaftes auf pathogene Bakterien. Inaug. Diss. Breslau, 1890, quoted by Tobler.

[5] Tobler: Ergeb. d. inn. Med. u. Kinderh., 1908, i, 495.

[6] Cassel: Arch. f. Kinderh., 1890, xii, 175.

cretion of hydrochloric acid and the motility are both diminished. The pasteurization or boiling of milk destroys the organisms which produce lactic acid but does not kill the spore-bearing bacilli,[1] which produce butyric acid. The latter causes the formation of butyric acid from carbohydrates and fat and possibly from protein. Whether butyric acid is formed or not depends, according to Tobler, not on the kind of food present, but on the type of bacteria. This may be in part true, because fermentation cannot take place without fermentative organisms. On the other hand, however, the food components necessary for fermentation must be present in sufficient quantity to supply the bacteria with fermentable material. The lactic acid bacilli and the butyric acid bacilli are the only organisms which usually play a part in the various processes of acid production in the stomach. The other bacteria (B. bifidus, B. acidophilus, B. coli and B. lactis aërogenes), which form acid are usually found only in the lower intestinal canal.

BACTERIOLOGY OF THE UPPER PART OF THE SMALL INTESTINE

The upper part of the small intestine, in comparison with the rest of the digestive canal, is relatively free from bacteria, both in the breast and in the bottle-fed infant. Hess [2] studied the bacteria of the duodenum during life by an ingeniously devised modification of his duodenal catheter. He found that in the new-born infants, who had received no food, the duodenum contained very few organisms, only from one to three growing on a plate. The organisms were staphylococci, Gram positive and Gram negative bacilli. Colon bacilli were not found. Infants in the first week of life also had very few bacteria in the duodenum and these were of the same varieties as those found soon after birth. There was more or less similarity between the bacteria of the stomach and the duodenum. The staphylococcus was the organism most frequently found at this age. Hess could not establish any relation between the amount of hydrochloric acid in the stomach, or of bile in the duodenum, and the number of bacteria. The presence or absence of icterus made no difference in the bacteriology of the duodenum in these babies. Cultures from the duodenal contents of older breast-fed babies showed from one hundred to two hundred colonies per plate. The plate method would not be satisfactory for

[1] (Bodkin's butyric acid bacillus appears to be relatively rare and it is possible that the gas-bacillus, which also forms butyric acid, is the one that is ordinarily found.)

[2] Hess: Ergebnisse der inn. Med. u. Kinderh., 1914, xiii, p. 530.

an aerobic bacteria such as the bacillus bifidus, which may also be found in this region. It must be remembered, therefore, that these results may not represent the true condition. Those from bottle-fed infants showed many more.[1]

There is evidence that, while the duodenum may be practically free from bacteria during the intervals between digestion, there is a relatively large population in the small intestine while the food is passing through it.[2] According to Ficker [3] and Moro [4] the flora of the upper small intestine is composed principally of short Gram negative rods (colon bacillus and bacillus lactis aërogenes) with an occasional isolated bacillus bifidus communis, bacillus acidophilus and butyric acid bacillus, and enterococci.

Under pathological conditions there may be an enormous increase in the bacteria in the small intestine. Prolonged fasts are regularly followed by an increase in the number of bacteria,[5] while all processes which cause an inflammation of the mucous membrane of the small intestine result in a diminution of its protective action against bacteria and a consequent increase in their numbers.

Moro [6] believes that there can be an endogenous infection of the small intestine. Such an infection is probably present in most disturbances of nutrition, both acute and chronic. The epidemic of severe diarrhea, associated with the presence of inflammatory products in the stools (blood and pus), described by Escherich [7] has been used as evidence for this point of view. The infants attacked were all young, their ages varying from four to ten months. The stools contained bacteria, which he called "blaue Bacillose" and which were proved to be, almost without question, "aciduric" [8] or acidophilic organisms. These organisms were probably identical with those which are normally present among the flora of the healthy nursling. Logan [9] on the other hand was unable to show that any colon-like organisms from cases with diarrhea showed any greater virulence to guinea pigs than the same organisms from babies not suffering from diarrhea.

[1] Moro; Jahrb. f. Kinderh., 1905, lxi, 870, may be consulted for the literature.

[2] Moro: Arch. f. Kinderh., 1906, xliii, 340; Kohlbrugge: Cent. f. Bact. Orig. 1901, xxix, 571; Landsberger: Diss Königsberg 1903, quoted by Kendall.

[3] Ficker: Arch. f. Hyg. 1905, liv. 354.

[4] Moro: Arch. f. Kinderh. 1906, xliii.

[5] Ficker: *loc. cit.*

[6] Moro: München. Gesellsch. f. Kinderh., 1907, xi, 15.

[7] Escherich: Jahrb. f. Kinderh., 1900, 52, 1.

[8] Kendall: Jour. Med. Research, 1911, xx, 117.

[9] Logan: Jour. Path. and Bact., 1914, xviii, 527.

BACTERIOLOGY OF THE LOWER PART OF THE SMALL INTESTINE AND OF THE LARGE INTESTINE

There are relatively few bacteria in the small healthy intestine down to the lower part of the ileum. There they begin to increase in number so that when the large intestine is reached they are very numerous. The types of bacteria which are commonly found, according to Kendall, are as follows:[1] The more commonly recognized bacteria are the B. bifidus (Tissier), the Mic. ovalis, the B. coli, the B. lactis aërogenes, and the B. acidophilus (Moro). These make up the normal nursling fecal flora. The B. lactis aërogenes appears in the upper levels of the tract, that is, the duodenum and jujunum; the Mic. ovalis in the lower jujunum and in the ileum to the ileocæcal valve; the B. coli and the B. acidophilus in the region of the ileocæcal valve, while the B. bifidus appears to dominate the ascending and transverse colon. This cannot be accepted without reservation since intestinal bacteriology is by no means so simple as it would appear from the foregoing statement. The remainder of the tract to the anus is relatively poorly populated in relation to the cœcum so far as living bacteria are concerned. This is due in part to the considerable degree of dessication of the fecal contents of the intestines and in part to the accumulation of waste products, which appear to inhibit the development of bacteria.

The character of the bacteria in the large intestine depends largely upon the food,[2] and, since human milk is a relatively homogeneous food, the tendency of the bacteriological flora of the breast-fed is toward uniformity. The bacteriological conditions in the artificially fed are, as would be expected, less consistent, because there is less uniformity in the food which they receive. The distinctive features of the stools of the artificially fed are the relative increase of Gram negative bacilli of the colon-aërogenes type and of cecal forms of the Mic. ovalis types. Coincidently, there is a decrease in the number of organisms of the B. bifidus type. The B. acidophilus is relatively more numerous and the B. bifidus less numerous.

BACTERIOLOGY OF THE STOOLS

The first stools (meconium), of the new-born are sterile, but they become infected shortly after birth. Within eighteen to twenty-four hours after birth, bacteria make their appearance in the stools and the meconium begins to disappear. The kinds

[1] Kendall: Jour. Med. Research, 1911–12, xx, 117.
[2] Moro: *loc. cit.*

and the number of bacteria which are found depend largely upon the season and the environment of the infant.[1] This is a period of mixed infection. The following organisms have been found in meconium: B. subtilis, B. coli,[2] B. bifidus, B. putrificus (Bienstock), butyric acid bacillus,[3] and enterococci.[4] These organisms undoubtedly gain entrance to the intestinal canal through both the mouth and the anus. Meconium is a poor culture medium, probably because of its small water content.

The B. bifidus appears about the beginning of the third day and persists throughout the nursing period. It is an obligate anaërobe (Kendall), Gram positive, and is the most characteristic organism of the nursling's stool. It is apparently independent of the quality of the stool and is present in the classical golden-yellow, homogeneous, pasty stool as well as in those which deviate from this character in consistency and color.[5] Although the B. bifidus dominates the typical field, other Gram positive bacteria can always be found. Other bacteria that have been described in the stools of the nursling are cocci, the B. lactis aërogenes, the B. coli, the B. acidophilus, butyric acid bacillus, the B. mesentericus and the B. aërogenes capsulatus (Welch).

The bacteriology of the stools of the artificially-fed infant is much more complicated than that of the breast-fed. No characteristic type of bacteria predominates, but there is a mixture of bacterial types. Culturally, the same species are found as in the stools of the breast-fed infant. The general picture is, however, apt to be Gram negative in contradistinction to that of the stool of the breast-fed infant, which is usually Gram positive. The B. coli communis, and the B. lactis aërogenes are the most numerous of these predominating Gram negative bacteria. A peptonizing bacillus, which is almost always absent from the stools of the breast-fed, has been recorded by Rodella.[6] Passini[7] found these types of butyric acid forming organisms, and isolated peptonizing organisms from the stools of apparently normal bottle-fed babies. The B. putrificus, the most typical example of a purely proteolytic organism, has been found in several cases.

The discussion as to the causes which influence the appearance

[1] Kendall: Wisconsin Med. Jour., 1913, xii, No. 1.
[2] Escherich: *loc. cit.*
[3] Moro: Jahrb. f. Kinderh., 1905, lxi, 885.
[4] Sittler: Habititationsschr., Wurzburg, 1909, quoted by Tobler.
[5] Moro: Jahrb. f. Kinderh., 1905, lxi, 687.
[6] Rodella: Zeits. f. Hyg., 1902, xli, 466.
[7] Passini: Zeits. f. Hyg., 1905, xlix, 135.

and disappearance of certain bacteria is of more than polemic interest, since it may lead to some conclusions which will have a practical application. Kendall's[1] view is given as follows: "The intestinal tract is sterile at birth, because the uterine cavity is sterile." The first infection takes place adventitiously. Any organisms which enter by the mouth or through the anus in the bath water, which can exist at body temperature, may find lodgment in the intestinal tract and may temporarily grow there. Many of the bacteria which thus succeed in entering the alimentary canal are spore-forming. During this period the food which is presented to them is largely detritus of fetal origin. At the beginning of the third day, when the breast milk has had a chance to thoroughly permeate the intestinal tract, new organisms appear, organisms which have a definite relationship to the type of food which is presented to them. It will be remembered that breast milk contains essentially 7% of lactose, about 3% of fat, and but 1½% of protein. Carbohydrate is, therefore, the dominant food. It is noteworthy that the organisms which appear in response to this diet are those whose metabolism is intimately associated with the utilization of sugar. These organisms thrive but poorly in a medium from which sugar is excluded. When other foods begin to replace the breast milk there is a definite change in the types of bacteria represented in the intestinal contents. The obligate fermentative bacteria, such as the B. bifidus, are replaced by more plastic forms and by the B. coli which can accommodate their metabolism rapidly to dietary alterations. The B. coli for example can thrive equally well on a medium in which carbohydrate is absent. It might appear from this rather definite alteration of types of bacteria in the intestinal tract following changes in the character of the food, that the food alone determined the intestinal flora. This may be somewhat influenced by the intestinal secretions. The essential feature, however, is the very direct relationship between the food and the bacterial response to it. This recognition of a relationship between food and bacteria in the intestinal tract is important in considering the intestinal flora, for it correlates the metabolism of the flora with the effects which it produces rather than attempting to establish indistinct relations between the morphology of the flora and these effects. These conclusions are supported by the work of Sittler,[2] and Bahrdt and Beifeld.[3]

[1] Kendall: Wisconsin Med. Jour., 1913, xii, No.1.
[2] Sittler: Centralbl. f. Bakteriol, 1908, xlvii, 14 and 145.
[3] Bahrdt and Beifeld: Jahrb. f. Kinderh., 1910, lxxii, Ergänzungsheft, 71.

Further investigations are necessary to throw more light on the subject which is not as simple as it appears. It seems probable that other factors besides the sugar alone may play an important part in determining the intestinal flora, most important of which is the relation of the sugar to the other food components, especially those which favor putrefaction.[1]

It is interesting to note that Noguchi [2] in studying the growth and characteristics of the B. bifidus was able to transform it in the laboratory from the strictly anërobic type (B. bifidus, Tissier) to the facultative aërobic type (B. acidophilus, Moro) and back again to the anërobic type. Logan [3] believes that the B. bifidus of the breast-fed is replaced by the B. acidophilus in the bottle-fed.

The Number of Bacteria in the Stools.—The most reliable figures as to the bacterial content of infant's stools are those obtained by Strassburger's method.[4] He found that the bacterial content of infant's stools was as follows:

TABLE 16

Age	*Food*	*Digestion*	*Per cent of bacteria in the dried stool*
2 months	cow's milk	normal	11.5
4½ "	" "	"	42.3
5 "	" "	?	35.2
2 "	human milk	normal	25.8
1 "	" "	dyspeptic	61.4

Leschziner [5] found that 2% to 28.4% of the dried stool of the healthy breast-fed infant was composed of bacteria, while from 6.52% to 29.4% of the total nitrogen was derived from bacteria. The newer and more perfect methods of Kramsztyk [6] and Klotz [7] show that the number of fecal bacteria varies with the kind of food and that it is the chemical composition of the food rather than its bacterial content which is of significance. Escherich [8] has shown that sterilization of the food has very little or no in-

[1] For a discussion of the action of the different sugars see Tobler.
[2] Noguchi: Jour. Exper. Med., 1910, xii, 182.
[3] Logan: Jour. Path. and Bact., 1914, xviii, 527.
[4] Strassburger: Zeits. f. klin. Med., 1902, xlvi, 413.
[5] Leschziner: Deutsch. aerzte Zeitung, 1903, No 17, 169.
[6] Kramsztyk: Zeits. f. Kinderh., 1911, i, 169.
[7] Klotz: Jahrb. f. Kinderh., 1911, lxxiii, 391.
[8] Escherich: Centralbl. f. Bacteriol., 1887, ii, 633 and 664.

fluence on the number of fecal bacteria.[1] Kramsztyk found the smallest number in the stools of infants fed on the breast. He found more in the stools of those fed on diluted cow's milk, and most in the stools of those taking both human and cow's milk. Carbohydrates, especially in the form of malt extract, increase the number of bacteria. Klotz, whose figures are somewhat higher, found that the maximum amount of fecal bacteria in the dried feces is from 30% to 36 %. He also found the smallest numbers in soap stools. Strassburger, however, found that 60% of the dyspeptic stool was made up of bacteria. Although counting the number of living bacteria is attended with many difficulties there can be but little doubt that a large proportion of the fecal bacteria are dead.[2]

Pathogenic Bacteria.—The typhoid bacillus and the various types of paratyphoid bacilli may be present in the stools of infants under the same conditions as in adults. The same is true of the tubercle bacillus and the cholera bacillus, as well as of other uncommon microörganisms, such as the bacillus of anthrax.

The various types of the dysentery bacillus are frequently found in the stools of infants. So also is the gas bacillus, as well as other closely allied microörganisms. When these organisms are found in considerable numbers in association with the symptoms of disease of the intestinal tract, as in infectious diarrhea, they are, in most instances, the cause of the disease. This is also the case when large numbers of streptococci are found in association with fever and diarrhea. The presence of a few of these organisms in the stools in cases of diarrhea does not prove, however, that they are the cause of the symptoms. They also may sometimes be found in small numbers in the normal stools of apparently healthy infants. Under these circumstances they are to be regarded simply as saprophytes.

[1] For further literature consult Gerhard, Erg. d. Physiol. (Asber-Spiro 1904, L. 107.)

[2] Eberle: Centralbl. f. Bacteriol., 1896, 19, 2.

CHAPTER VIII

THE STOOLS IN INFANCY

The examination of the stools is of the greatest aid in the diagnosis of the nature of disturbances of digestion in infancy. It furnishes information which cannot be obtained so quickly and accurately in any other way. The clinical examination of the stools is, moreover, not a difficult matter. It requires but little time and but little apparatus. The methods are simple and easy to learn. It is fortunately not necessary to make use of the more complicated methods of analysis in every-day work, because the simple methods of clinical examination give information which is as useful for practical purposes as that furnished by the more accurate and elaborate procedures.

The character of the stools depends primarily on the composition of the food. It is modified by the digestive powers of the individual infant and by the amount and rapidity of absorption of the products of digestion. The amount of absorption depends to a considerable extent on the rapidity with which the intestinal contents pass through the intestinal tract. The character of the stools also depends on the nature of the bacterial flora of the intestine. This is dependent, to a large extent, on the nature of the food. The influence which the bacteria exert depends largely on the digestive power of the infant and the rapidity with which the products of digestion are absorbed. The more feeble the digestive power and the slower the absorption, the greater the effect of the bacteria. It is often difficult, therefore, to draw conclusions from the examination of the stools as to just what is going on in the intestines. It is usually possible, however, to determine whether any given food element is properly digested and assimilated or not, and in many diseased conditions to tell what element is at fault. The presence of an improperly digested food element in the stools does not necessarily show, however, that this is the element primarily at fault, although it usually is. Fat curds may, for example, be present in the stools as the result of the fermentation of sugar, the excessive peristalsis resulting from the irritation caused by the products of the fermentation of sugar preventing the proper absorption of the fat. When the element at fault is

known, it can be reduced and the necessary amount of the reduction determined by repeated examination of the stools.

MECONIUM

The meconium is dark brownish-green in color. The first meconium passed is semi-solid, having been partially dried out in the large intestine. The remainder is more viscid. It is composed of mucus, bile, intestinal secretions and cells, with vernix caseosa, epithelial cells and hairs swallowed with the amniotic fluid. The meconium stools are replaced after from two to four days by stools composed of bile-tinged mucoid intestinal secretions. They are usually dark-green, but may be dark-brown or brownish-yellow, according to whether the bile pigment is in the form of bilirubin or biliverdin. The change to the normal fecal stool occurs gradually during the next two or three days.

The stools of the breast-fed infant differ normally in their characteristics from those of the infant fed on cow's milk. The addition of starch to cow's milk changes the character of the stools. The appearance of the stools varies also with the kind of sugar which is added to the milk.

THE STOOLS OF BREAST-FED INFANTS

During the first few weeks or months of life, the breast-fed infant has three or four stools daily. These are of about the consistency of pea soup and of a peculiar golden-yellow color. The odor is slightly sour or aromatic, and the reaction slightly acid. The number of stools gradually diminishes to two or three in the twenty-four hours and the consistency becomes more salve-like. The other characteristics are the same. The golden-yellow color is due to bilirubin, which, on account of the short time which it remains in the intestine, the relatively low protein content of the milk and the low reducing power of the infant's intestine, passes unchanged through the intestinal tract. The odor is due to a combination of lactic and fatty acids. The acid reaction is due to the relative excess or fat over protein in the milk.

It is not uncommon for babies, even when they are thriving on the breast, to have a large number of stools of diminished consistency and of a brownish color. The examination of the breast-milk in such instances usually shows that the proteins are high. It is also not unusual to find many soft, fine curds, and sometimes mucus in the stools of healthy breast-fed babies. Such

stools are undoubtedly abnormal. It is unwise to pay too much attention to them, however, if the baby is gaining in weight and appears well. The breast-fed infant will often go weeks or months without a normal stool and yet thrive perfectly, while if a baby had such stools when it was taking cow's milk it would not thrive and would show distinct evidences of malnutrition. It is, therefore, not only unnecessary, but distinctly wrong, to wean a baby simply because the stools are abnormal, if it is doing well in other ways.

THE STOOLS OF INFANTS FED ON COW'S MILK

Infants that are thriving on cow's milk mixtures have, as a general rule, fewer movements in the twenty-four hours than do breast-fed babies, and these movements are firmer in consistency. Slight constipation is not uncommon after the first few months and is not pathological. The color of the stools is a lighter yellow. This is probably due in part to the relatively larger amount of protein and in part to the fact that some of the bilirubin is converted into hydrobilirubin. When the relative proportions of fat and protein in the mixtures are approximately the same as they are in breast milk the odor and reaction of the stools are essentially the same as when the baby is taking breast milk. When infants are given whole cow's milk or simple dilutions of cow's milk, so that the percentage of protein is about the same as that of the fat, the odor is slightly modified toward the fecal or cheesy, because of the action of bacteria on the casein. The reaction becomes alkaline for the same reason.

Skimmed Milk Mixtures.—When infants are fed on skimmed milk or on mixtures containing very small percentages of fat and high percentages of protein, the stools have a slightly brownish-yellow color, a slightly cheesy or foul odor and a strongly alkaline reaction, because of the longer stay of the casein in the intestine and the consequently greater opportunity for bacterial action and for the change of bilirubin into hydrobilirubin. In most instances the stools have, when spread out, a peculiar, smooth, salve-like appearance like those from buttermilk.

Whey and Whey Mixtures.—When infants are fed on whey to whey mixtures low in fat, the stools have essentially the same characteristics as those from skimmed milk, except that they are usually browner. Whey has a laxative action in many instances and sometimes has to be given up on this account.

Starch Mixtures.—When starch is added to cow's milk mixtures the color of the stools becomes more distinctly brownish and

the reaction tends toward the acid. The odor is more aromatic. The source from which the starch is derived apparently has but little effect on the number of stools, although it is commonly thought that barley starch is constipating and oatmeal starch laxative. The action, if there is any, seems to vary with the individual infant. It must not be forgotten in this connection that most starch flours contain small brownish specks which are the remains of the husks (*cellulose*). These specks pass through the gastrointestinal tract unaffected and appear in the stools. They are sometimes mistaken for intestinal sand or for dirt.

Dextrin-Maltose Mixtures.—The addition of the various combinations of the dextrins and maltose to cow's milk mixtures changes the color of the stools to a distinct brown, tends to make the reaction acid and to increase the acidity of the odor. These sugars usually have a laxative influence but sometimes constipate. In general, the higher the proportion of maltose, the greater is the laxative action. When these combinations of the dextrins and maltose, or the malted foods, which amount to the same thing, are given without milk, the stools are dark-brown, sticky, acrid in odor and acid in reaction.

Buttermilk and Buttermilk Mixtures.—The stools of infants fed on buttermilk and buttermilk mixtures are of a peculiar shiny, salve-like appearance, grayish-brown or olive-green in color, alkaline in reaction and have a very characteristic acrid odor.

Animal Food.—When beef juice or broth is added to the infant's diet the color of the stools is changed to brown, while the odor becomes fecal and the reaction alkaline from the action of bacteria on the proteins. It is not uncommon when babies are taking beef juice to have one portion of the stool brown with the remainder yellow, the dividing line between the two colors being very distinct. The dark color represents, of course, the meal at which the beef juice was taken.

THE STARVATION STOOL

The starvation stool is composed of bile, the intestinal secretions and bacteria. It resembles the meconium in appearance. It is small, and brownish or brownish-green in color. It is sometimes constipated, sometimes loose. It usually has a stale odor like that of starch or paste. In some cases it has the odor of acetic acid as the result of action of microörganisms. It not infrequently contains bile-stained mucus.

REACTION OF THE STOOLS

The reaction of the normal stool depends on the relation between the fat and protein in the food. When there is a relative excess of fat the reaction is acid; when there is a relative excess of protein the reaction is alkaline, the reaction depending, in the one case, on the products of the decomposition of fat, in the other on the products of the decomposition of protein. The carbohydrates have but little effect on the reaction of the normal stool. When the carbohydrates are in excess, or when there is fermentation of the carbohydrates as the result of bacterial action, the acidity of the stools is markedly increased. Stools which irritate the buttocks are invariably acid in reaction and in many instances this excessive acidity is due to the fermentation of carbohydrates. Frothy stools are usually acid in reaction and the result of the fermentation of carbohydrates. Sometimes, however, the frothiness is caused by gases formed during the decomposition of protein. The reaction of the stools is best tested by placing wet red or blue litmus paper on a fresh surface of the stool. It is, however, except when there is excessive acidity, of comparatively little importance clinically.

ODOR OF THE STOOLS

The odor of the stools depends on the composition of the food, the rapidity of the absorption of the products of digestion and the degree of the bacterial activity. The fats give the odor of butyric or lactic acid to the stools. The carbohydrates, if thoroughly utilized, do not affect the odor; if not utilized, they give the odors of lactic, acetic or succinic acids. The proteins give cheesy odors of various sorts, sometimes those of skatol, indol and phenol.

The odor of the normal stool and the influence of variations in the diet upon it have already been mentioned. The stools of fat indigestion may have a strong odor of butyric acid, those of protein indigestion various cheesy or putrefactive odors as the result of the decomposition of the protein by bacteria. When several elements of the food are improperly digested the odor is a combination of those resulting from the decomposition of the various elements. The stools of cholera infantum are almost odorless. Stools composed almost entirely of mucus have a peculiar aromatic odor resembling that of wet hay. When there are deep ulcerative or gangrenous processes in the intestine, the stools have a putrefactive or gangrenous odor.

COLOR OF THE STOOLS

The normal variations in the color of the stools according to the composition of the food have already been mentioned. Abnormalities in the color are very common. The color of the stool must not be judged from the outside, as it may change very rapidly as the result of drying and exposure to the air. The stool must be broken up or smoothed out and the inside examined.

Green.—The most common abnormal color is green. The shade of green may vary from a very delicate light grass-green to a dark spinach-green. In a general way, the darker the green, the greater its significance. When a stool is otherwise normal, a very light grass-green color is of no practical importance. The change from yellow to green after the stool is passed is not abnormal. The green color is, in the vast majority of instances, due to the change of bilirubin to biliverdin. There is much doubt as to the cause of this change. It is probable that it may be due to either excessive acidity or alkalinity of the intestinal contents or to the presence of some oxidizing ferment. The green color is not characteristic of any special type of disease. In some instances it is due to the action of the bacillus pyocyaneus. If it is due to bacterial action, the addition of nitric acid decolorizes the stool. If it is due to biliverdin, the addition of nitric acid gives the characteristic colors of Gmelin's test.

Gray.—The next most common abnormal color is gray. This is due, as a rule, to the absence of bile and the presence of some form of fat, usually soap, in the stool. It must be remembered, however, that there may be bile in the stool even when it is gray, the bile pigment being in the form of the colorless leucohydrobilirubin. It is never safe, therefore, to conclude that there is no bile in the stool without a chemical examination. The easiest and most satisfactory test is that with corrosive sublimate. This test is, however, not always accurate. When the stools are gray at birth or become so within a few days after birth, the lesion is usually a congenital obliteration of the bile ducts. It may be, however, an atresia of, or an obstruction in, the intestine. When the gray color appears later, and especially when it is associated with the presence of large amounts of mucus, the trouble is usually in the duodenum.

White.—White stools are due to the presence of undigested fat in the form of soaps. The white stools may be soft, looking like curdled milk or, more often, hard and dry, resembling the stools of a dog which has been eating bones.

Black.—The black stool, while in rare instances due to the presence of changed blood, is usually due to the action of some drug. This drug is ordinarily bismuth, but sometimes iron or charcoal. In this connection it is well to remember that, when there is no sulphureted hydrogen in the intestine, bismuth may pass through the intestinal tract without being changed in color. The administration of a grain or two of sulphur in the twenty-four hours will turn the stools black. Whether this is of any advantage or not is questionable.

Blue.—The stools are sometimes of a slaty-blue color. This color is due to some change in the bile pigments and is of no more significance than the green color.

Pink.—It is very common to see a pink stain on the diapers about a stool which is otherwise normal or nearly so. This pink stain is of no especial significance and is due to some unknown change in the bile pigment.

ABNORMAL CONSTITUENTS

Curds.—The most common abnormal constituents of the stools are curds. There are two kinds of curds, one primarily composed of casein, the other composed mainly of fat, mostly in the form of fatty acids and soaps. The small amount of fat in the casein curds and the small amount of protein in the fat curds are merely incidents. The casein curds vary in size from that of a bean to that of a pecan nut. They are usually white, sometimes yellow in color. They are firm and tough, cannot be broken up by pressure, and sink in water. When placed in formalin they become as hard as rocks. They are insoluble in ether. The fat curds are small, varying in size from that of a pinhead to that of a small pea. They vary in color from white to yellow or green, according to the general color of the movement. They are easily broken up by pressure and when shaken up in water tend to remain in suspension. They are soluble in ether to a considerable extent after acidification and heating, and are unaffected by formalin.

Mucus.—Mucus can be detected in small amounts under the microscope in the majority of normal stools and is almost invariably present in abnormal stools. It is never present macroscopically in normal stools, but is very often visible in the abnormal. It does not denote any special form of disease, but merely an excessive secretion of the mucous glands of the intestine as the result of some irritation. When it is thoroughly mixed with the feces it usually comes from the small intestine; when in combination

with a clay-colored stool, from the duodenum; when on the outside of a constipated stool, from the rectum. Stools composed mostly or entirely of mucus and blood indicate either severe inflammation of the colon or intussusception. Undigested starch is often mistaken for mucus. It can be distinguished by the addition of some preparation of iodine, which stains starch blue but does not affect the mucus. The suspected material should be taken off of the diaper in order to avoid possible confusion because of the presence of starch on the diaper. It is of importance not to use too strong a solution of iodine.

Blood.—Blood on the outside of a constipated stool indicates a crack of the anus. Blood mixed with mucus indicates either severe inflammation of the large intestine or intussusception. Blood in infancy is seldom due to hemorrhoids. In rare instances the hemorrhage may come from an intestinal polyp. Hemorrhage from the bowel in the first few days of life is ordinarily a symptom of hemorrhagic disease of the new-born.

Pus.—Pus indicates severe inflammation of the large intestine. It is usually not present early in the disease, but appears later. When the infants survive the acute stage it persists into convalescence. Pus can be found with the microscope in nearly every case of inflammation of the colon, but is of no special significance unless visible macroscopically.

Membrane.—Membrane indicates very severe inflammation of the large intestine and is rarely seen, the patients usually dying before membrane appears in the stools.

Other abnormal constituents are undigested masses of food, foreign bodies which have been swallowed, and worms.

MICROSCOPIC EXAMINATION OF THE STOOLS

The macroscopic examination of the stools affords data sufficiently reliable for clinical work in the great majority of instances. It may, however, lead to erroneous conclusions, especially with regard to the amount of fat and undigested starch. Fatty and starchy stools sometimes appear perfectly normal macroscopically, and microscopic examination will alone prevent mistakes. It is advisable, therefore, in all but the plainest cases, to examine the stools microscopically as well as macroscopically. The microscopic examination of the stools is not a difficult procedure, and can be carried out in ten minutes or less by anyone accustomed to it. Controls of the microscopic examination by chemical examination of the stools have shown that it gives results sufficiently reliable for

clinical purposes. A certain amount of experience is necessary, however, in order to recognize the variations in the microscopic picture. The stools normally show a certain amount of fat in some form or other, but never show undigested starch. The chief difficulty in the microscopic examination is to learn to recognize the normal variations in the amount of fat.

The feces, if hard, are first rubbed up with a little water. It is important not to dilute them too much. If not hard, they are thoroughly mixed. A small portion is then spread out very thin on a slide under a cover-glass and examined for the presence of undigested tissues or pathological elements, such as blood, pus and eggs of parasites.

The second portion is stained with Lugol's solution (iodine 2, potassium iodide 4, distilled water 100) and examined for starch. The starch granules stain blue or violet. Certain microbes also stain blue. These, the so-called iodophilic bacteria, are associated with faulty carbohydrate digestion, and, when found alone without other symptoms, are suggestive of a beginning disturbance in the digestion of the carbohydrates. Before concluding that undigested starch is present, all possibility of contamination with baby powders must be eliminated. A diagnosis of starch indigestion should never be made unless the characteristic form of the starch granules is made out.

A third portion, undiluted with water, is stained with a saturated alcoholic solution of Sudan III. The neutral fat drops and fatty acid crystals stain red. Soap crystals do not stain with Sudan III. After this specimen is examined and the microscopic picture is clear, a drop of glacial acetic acid is allowed to run under the cover-glass, is thoroughly mixed in, and then heated until it begins to simmer. It should not be boiled, because, if it is, the fat is likely to be driven to the edge of the cover-glass and lost. This procedure converts the soap into neutral fat and fatty acids which appear as large stained drops. They crystallize upon cooling. They usually retain the red stain. Any increase in the amount of fat after the addition of acetic acid indicates the presence of a corresponding amount of soaps.

This method of staining, while it enables us to distinguish between the amount of neutral fat and fatty acids together, on the one hand, and of soaps, on the other hand, does not make it possible to determine how much of the fat is in the form of neutral fat. This point can be determined by the use of carbol-fuchsin. The stain may be prepared as it is for staining tubercle bacilli. This may be too strong, however, and, if so, the solution should be

diluted with an equal amount of 95% alcohol. Carbol-fuchsin does not stain neutral fat, but stains fatty acids a brilliant red and soaps a dull red. The following table shows the difference in the staining properties of neutral fat, fatty acids and soaps.

TABLE 17

Stain	*Neutral fat*	*Fatty acids*	*Soaps*
Sudan III	Drops staining orange red	Drops staining red, or crystals staining orange-red	Crystals do not stain
Diluted carbol-fuchsin	Drops do not stain	Drops and crystals stain brilliant red	Crystals stain dull red

It is possible, therefore, by using these two stains in conjunction, to determine accurately enough for clinical purposes the relative proportions of neutral fat, fatty acids and soaps in the stool. An excess of neutral fat indicates that the digestion of fat is not carried on normally; an excess of fatty acids and soaps, that the digestion is normal but absorption is abnormal. It must be remembered in interpreting the importance of an excess of fat in the stool, that the younger the baby, the less is the significance of an excess of fat and vice versa.

It is well to examine the specimen first with a low-power objective and later with a high-power in order to bring out the detailed structure.

THE BACTERIOLOGIC EXAMINATION OF THE STOOLS

Our knowledge of the bacteriology of the disturbances of digestion and of the various inflammatory diseases of the intestine is so limited at present that no conclusion of clinical importance can be drawn from the microscopic examination of the stools, the only exception being possibly the presence of large numbers of iodophilic bacteria, which, as already stated, point to disturbance of the digestion of the carbohydrates. In general, Gram-positive bacteria will predominate in an acid and Gram-negative in an alkaline stool. The determining factors are the same as those which cause the reaction of the stool.

STOOLS OF DIFFERENT TYPES OF INDIGESTION

The characteristics of the stools in some of the more marked types of indigestion are fairly definite. They are summarized below.

The Stools of Fat Indigestion.—Undigested fat may show it-

self in the stools in the form of small, soft curds, by giving a greasy, shiny appearance to the stool or by giving it a gray or white color. The small curds are, of course, easily recognized. Sometimes the stools have an oily appearance and the color is that of Indian meal. The presence of undigested fat may be shown roughly by rubbing some of the stool on a piece of smooth, soft paper. If there is an excess of fat, the paper will have, when dry, the appearance of oiled paper. When there is an excess of neutral fat, the stools are often of a creamy consistency. If the fat is largely in the form of soaps, the stools are usually clay-colored or very dry and crumbly. The reaction is highly acid. The odor is rancid, like that of butyric acid. Microscopically, these stools show a large excess of fat in various forms.

The Stools of Carbohydrate Indigestion.—The character of the stools of carbohydrate indigestion depends on whether the disturbance is in the digestion of starch alone without bacterial action or in the digestion of either or both starch and sugar with bacterial fermentation. When the disturbance is solely in the digestion of starch and the bacterial fermentation is not marked, the stools are brown or golden-yellow in color and salve-like in consistency. They may, as already stated, appear macroscopically normal. In rare instances they are very dry and brittle. The reaction is acid. The odor is acid, the character of the odor depending on the form of acid present. The iodine test will often show the presence of undigested starch macroscopically. Microscopically these stools show undigested starch by the iodine test, and an excess of iodophilic bacteria.

When bacterial fermentation is added to the disturbance of digestion of either starch or sugar, the stools are loose, green and frothy. The reaction is acid from the presence of lactic, acetic or succinic acid. The odor is acid, the character of the odor depending on the form of acid present. These stools often cause excoriation of the buttocks and genitals.

The Stools of Protein Indigestion.—The presence of large, tough curds in the stools is, of course, evidence of protein or rather casein indigestion. In general, however, the stools of protein indigestion are loose, brownish in color, alkaline in reaction and with a foul odor, the odor in some instances being fecal, in others cheesy, in others a combination of the two.

Mixed Forms of Indigestion.—Mixed types of stools as the result of mixed types of indigestion modified by bacterial fermentation and decomposition are far more common than the pure types alone and are often very difficult to interpret.

The examination of the stools gives information regarding the digestive processes which cannot be obtained in any other way. Without such examination the treatment of disturbances of digestion is always unscientific and often irrational. The macroscopic examination of the stools affords information of the greatest importance, but in many instances will lead to error unless the microscopic examination is also made. The microscopic examination is a simple one and requires but little time. The results obtained from it are, for practical purposes, as reliable as those obtained from the chemical examination. The stools should be examined both macroscopically and microscopically in every disturbance of the digestion in infancy.

SECTION II

BREAST FEEDING

CHAPTER IX

GENERAL CONSIDERATIONS

It is generally recognized that the natural food for the human infant is human milk, that breast-fed babies are more likely to live than the artificially-fed and that, as a class, they are healthier, more vigorous and more resistant. Few appreciate, however, how much greater the mortality is in the artificially-fed than in the breast-fed. There are many statistics to prove this fact. It is hardly necessary, however, to give more than a few of them.

Mortality.—In Berlin, where the character of the feeding of all living children is determined by the census, during the five years, 1900 to 1904, only 9% of the infantile deaths were in breast-fed babies.[1] The Department of Health of New York City estimates that over 85% of all infantile deaths are in those artificially fed.[2] Davis [3] found that in Boston, in 1911, 74% of the deaths of infants over two weeks of age were in the artificially-fed, and calculates that in Boston the bottle-fed is six times as likely to die as the breast-fed infant. Luling,[4] in a study of 13,952 children born in Baudeloque's clinic, found an infant mortality of 14% in the breast-fed, 31% in those who were bottle-fed by their own mothers, and 50% in those who were bottle-fed by strangers. Armstrong,[5] in a study of 1,000 infants in Liverpool, in 1903, found that 8.4% of the breast-fed babies died in the first year against 22.8% of the artificially-fed. Of 1,000 fatal cases of diarrheal disease investigated by the Health Department of the City of New York, in 1908, only 90 had previously been entirely breast-fed.[2] Further evidence of the effect of breast feeding on the

[1] Graham: Journal A. M. A., 1908, li, 1045.
[2] Holt: Journal A. M. A., 1910, liv, 682.
[3] Davis: Amer. Jour. Diseases of Children, 1913, v, 234.
[4] Luling: Thèse de Paris, 1900.
[5] Armstrong: British Jour. Children's Diseases, 1904, i, 115.

infant mortality is the fact that during the Siege of Paris, 1870–71, while the general mortality rate doubled, the infant mortality rate fell from 330 to 170 per thousand deaths, the reason being that the women, having no other food to give their babies, had to nurse them.[1]

Relative Frequency of Breast Feeding.—The relative frequency of breast feeding varies in different countries and in different races. In Japan, breast feeding is the rule. In Greenland, and among the Eskimos, artificial feeding is practically unknown. The proportion of breast-fed babies is much smaller in other countries. Nordheim,[2] for example, found, as the other extreme, that only 3.6% of 1,000 women coming to the Women's Dispensary in Münich, nursed their babies longer than three months. Davis,[3] from an investigation made in 1911, estimated that 68% of all Boston babies between the ages of two weeks and one year were breast-fed, while the Board of Health of the City of New York estimates that about 85% of the infants in New York are breast-fed.[4] Holt,[4] however, thinks that, as these data were gathered largely from the tenement district statistics, they are too high, and that 80% is nearer the truth for the entire population. Koplik [5] found that 10% of 1,007 infants, seen in private practice in New York City, were exclusively breast-fed, 30% exclusively bottle-fed and 60% breast and bottle-fed. Forty per cent of these were weaned before the fourth month.

Ability of Women to Nurse Their Babies.—There are two reasons why women do not nurse their babies. They are either unable or unwilling. There is much difference of opinion as to what proportion of women are really able to nurse their babies, although it is generally conceded that a large proportion of those who do not nurse their babies could nurse them, if they thought they could or were compelled to do so. Nordheim [2] found that of 1,000 women 642 had never nursed, and that 86.7% of these had no good reason for not nursing. Dluski [6] found that 99% of the women in the Maternity Department of Professor Pinard, in Paris, were able to nurse their babies. Holt [4] estimates, however, that not over 25% of the well-to-do and cultured women of New York City are able to nurse their babies over three months.

[1] Brehmer: Wochenschr. f. Säuglingsfürsorge., 1907, 209.
[2] Nordheim: Archiv. f. Kinderheilk., 1901, xxxi, 89.
[3] Davis: Amer. Jour. Diseases of Children, 1913, v, 234.
[4] Holt: Journal A. M. A., 1908, li, 1045.
[5] Koplik: Journal A. M. A., 1912, lviii, 75.
[6] Dluski: Thèse de Paris, 1894.

There is no doubt that a far larger proportion of women can nurse their babies than was formerly supposed. Martin [1] found that in Würtemberg, where formerly only 41% of the women in the clinics nursed their babies, 100% are now capable. Constant instruction at the *Consultations des Nourrissons*, in France, has increased the number of cases of maternal feeding among the poor by 20% or 30%. The experience at similar institutions in this country has been the same. There is a general belief, moreover, although there are no figures to prove it, that the ability of women in the wealthier and more highly educated classes in this country to nurse is steadily increasing.

Unwillingness to Nurse.—The main reason why women do not nurse their babies is that they do not appreciate its importance. This is due to a considerable extent to the fact that they do not receive proper advice from doctors, nurses and midwives, who, unfortunately, are themselves in many instances ignorant of the importance of breast feeding. The unwillingness to nurse among the wealthier and fashionable classes is in part because they are unwilling to sacrifice their own pleasure and convenience, in part because it is not fashionable in certain circles to nurse, and in part because of the opposition of their husbands, who do not wish to be deprived of their wives' society. Many of them feel, moreover, that on account of the great improvement in artificial feeding, their babies will do well enough, even if they do not nurse them. The unwillingness of women among the poorer classes to nurse their babies is, in many instances, due to the fact that on account of poverty they are obliged to go to work. Ignorance of the advantage of breast feeding plays a greater part in their unwillingness to nurse than among the better educated, as do also the advertisements of proprietary foods.

Contraindications to Breast Feeding.—A woman with active pulmonary tuberculosis should not nurse her baby, because of the great danger of infection of the baby. It is usually inadvisable for a woman with healed tuberculosis, pulmonary or otherwise, or with closed tuberculosis, to nurse her baby, because of the danger of starting up or increasing the activity of the process. Although tubercle bacilli are sometimes present in the milk of tuberculous women, the danger of infection from this cause is negligible. Syphilis is not a contraindication to nursing because, if the mother has active syphilis the baby has been infected before birth, and if the baby has syphilis, the mother always has it. Insanity is a contraindication to nursing as is, in most instances, epilepsy. Very

[1] Martin: Archiv. f. Gyn., 1905, lxxiv, 513.

delicate or feeble women and women suffering from serious chronic diseases should not nurse their babies, partly because their milk is usually of poor quality, and partly because the strain of nursing is certain to do them serious harm. It is usually inadvisable for women that have had severe hemorrhages, who are septic or who have nephritis to nurse their babies. Women suffering from puerperal eclampsia should not nurse their babies, because of the danger of the production of serious or even fatal symptoms in the babies, which are probably manifestations of anaphylaxis. Women who have been unable to nurse previous children satisfactorily can hardly be expected to nurse. It is wiser, however, for them to make the attempt because they are sometimes able to do it, although unsuccessful in the past.

A certain number of infants are unable to nurse because of deformities of the lips and mouth. Premature infants are often too weak to nurse, as are some congenitally feeble babies. Such babies should not, however, be deprived of the advantages of human milk. The milk should be pressed from the breast, or drawn with a breast pump and fed to the baby with a dropper, spoon or Breck feeder, or through a tube.

CHAPTER X

HUMAN MILK. CHEMISTRY AND BIOLOGY

The Breast Glands.—Glands which secrete milk are present, as a rule, in the female mammal only during and after pregnancy. A few drops of milk may be squeezed from the breasts before parturition, but, generally speaking, milk is present in them only after delivery.

According to Czerny and Keller [1] if the infant does not empty the breasts and they fill up again with secretion, there is a change in the composition of the milk as the result of the absorption of its different components. It is, therefore, necessary to differentiate between the milk of women whose breasts are regulated and sufficiently emptied during nursing and that of women whose breasts are not sufficiently emptied. In the first there is no absorption of the milk components in the glands, while in the latter the chemical composition is more or less changed by absorption. They designate the latter as colostrum. Under this term they include all milk in which there has been any absorption; not only the milk in the breasts during pregnancy and the first few days postpartum, but also the milk when the secretion is in the process of drying up.

Colostrum.—All authors agree that the milk excreted during the first few days postpartum differs essentially from that after lactation is well established. It is of a deep lemon-yellow color. This color is present only during the first few days postpartum and is never seen at any later stage of lactation. Czerny (p. 408) believes, on the basis of his own work, that this color is due to a coloring matter contained in the fat drops. The colostrum is not as sweet as the later milk. It is coagulated into solid masses by heat. This depends, according to Tiemann,[2] on the presence of a globulin, which coagulates at 72 C. (161.6 F.). The amount of cholesterin and lecithin is greater than in milk.[3] The fat in colostrum contains less of the volatile fatty acids than does normal milk.[4]

[1] Czerny and Keller: Des Kindes Ernährung, Ernährungsstörungen, und Ernährungstherapie, Leipzig and Wien, 1906, i, 407.

[2] Tiemann: Ztschr. f. Physiol. Chem., 1898, xxv, 363.

[3] Völtz: Oppenheimer's Handbuch der Biochemie, Jena, 1910, iii, I, 382.

[4] Nilson: Maly's Jahresb., 1891, xxi, 142.

It is obvious that only those analyses of colostrum which have been made during the first days postpartum are of any value, as later it is mixed with milk. The specific gravity of colostrum ranges from 1.028 to 1.072, the average being about 1.040.[1] It has a strongly alkaline reaction.

J. König [2] gives the following percentages as the average of five analyses of early human colostrum: Water, 86.4; nitrogenous substances, 3.07; fat, 3.34; lactose, 5.27; salts, 0.40.

TABLE 18

COMPOSITION OF COLOSTRUM AS DETERMINED BY VARIOUS INVESTIGATORS (CZERNY AND KELLER)

Author	*Day, postpartum*	*Fat, per cent.*	*Lactose, per cent.*	*Protein, per cent.*	*Nitrogen, per cent.*	*Ash, per cent.*	*Solids, per cent.*
Pfeiffer [3]	1	2.59	2.76	9.75	.....	0.408	.....
Pfeiffer	2	2.17	3.50	7.45	.....	0.340	.....
V. & J. Adriance [4]	2	3.77	5.39	3.31	.....	0.27	12.78
Camerer and Söldner [5]	26–51 *	4.08	4.09	....	0.928	0.48	16.04
	56–61 * †	3.92	5.48	....	0.508	0.41	14.12
	26–48 *	1.67	5.20	....	0.336	0.36	10.32
	48–69 * †	2.02	5.08	....	0.226	0.40	10.12

* Hours. † Same woman.

Pfeiffer,[3] found that the nitrogenous substances in human milk were as follows: First day, 8.6%; third to seventh day, 3.4%; during second week, 2.28%; in second month, 1.84%; in seventh month, 1.52%. The amount of sugar increases as the protein in human milk diminishes. The mineral composition of colostrum and breast milk is materially different. Table 19 shows the composition of one hundred grams of colostrum as compared with one hundred grams of milk.[6]

The findings of Burr, Bermerich and Berg [7] were somewhat different. They found that colostrum contained twice the amount of phosphorus, magnesium and calcium normally present in milk after lactation is well established.

Colostrum Corpuscles.—Microscopically the fat droplets in colostrum are more unequal in size than in ordinary milk. The

[1] Burr, Bermerich and Berg: Chem. Ztg., xxxvii, 69–71, 97–101.
[2] König, J.: Die Menschl. Nährungs u. Genussmittel, Berlin, 1904, ii, 598.
[3] Pfeiffer: Jahrb. f. Kinderh., 1883, xx, 365.
[4] Adriance, V. and J.: Archives of Pediatrics, 1897, xiv, 22.
[5] Camerer and Söldner: Ztschr. f. Biol., 1898, xxxvi, 277.
[6] Birk: Monatschr. f. Kinderh., 1910–1911, ix, 595.
[7] Berg: Chem. Ztg., xxxvii, 146.

TABLE 19

COMPOSITION OF 100 GM. COLOSTRUM AS COMPARED WITH MILK (BIRK)

Colostrum (Birk)		*Human milk*	
Ash	0.2814	0.0198	Langstein and Meyer
		0.2 –0.25	Abu-Neuberg
Calcium	0.0360	0.0328–0.0343	Bunge
		0.0378	Camerer and Söldner
Magnesium	0.0093	0.0064–0.0065	Bunge
		0.0053	Camerer and Söldner
Potassium	0.077	0.078 –0.0703	Camerer and Söldner
		0.088	Camerer and Söldner
Sodium	0.0544	0.0357	Camerer and Söldner
Phosphorus	0.1137	0.0473–0.0469	Bunge
		0.0591	Camerer and Söldner

colostrum also contains large numbers of granular bodies, known as "colostrum corpuscles." They are four or five times as large as the leukocytes, are nucleated and are full of fat droplets. They are characteristic components of milk at the beginning of lactation, and are not found in later lactation. They have ameboid motion.[1] Czerny identified them as large leukocytes, whose cell membranes are completely filled with fat drops. These fat drops are smaller than those in the milk. He was able to demonstrate that the leukocytes of frogs possess the power of emulsifying fat drops and explains their small size in this way. He further emphasized the fact that it had previously been thought that these bodies were only present in the milk during the first days of lactation. Buchholz [2] noticed in 1877, however, that the colostrum bodies reappeared in the milk when nursing was stopped and the milk was drying up. Czerny repeated his work and found that the colostrum bodies always reappeared in the milk when lactation was interrupted for a few days, and that their numbers increased in direct proportion to the length of time which had elapsed since the breasts were emptied. He concluded that colostrum corpuscles were always present when milk was formed in the breasts but was not withdrawn and that they disappeared when the breasts were sufficiently emptied of milk. Animal experiments show that the colostrum bodies pass from the breasts into the lymphatics. These colostrum corpuscles contain neutrophilic granules.[3] According to

[1] Czerny and Keller, page 409.
[2] Czerny and Keller, page 410.
[3] Cohn: Virchow's Arch. f. path. Anat., 1900, clxii, 187.

Deville,[1] they disappear from the milk between the eighth and tenth day in 51% of the cases. They may, however, in rare instances persist for many weeks.[2]

They are also phagocytic, in that they will consume bacteria. They have been shown to consume staphylococci, the colon bacillus, and the tubercle bacillus.[3]

When the breasts are not completely emptied, the protein and sugar are reabsorbed into the body earlier than the fat, which is taken up by the colostrum corpuscles only after five or six days. The sugar may appear early in the urine. The albumins in milk have a different hemolytic action from those in the blood of the same species, while those in colostrum react the same. On the basis of these facts, Bauer [4] argues that the proteins in colostrum are a direct transudate from the blood, while those in milk are manufactured by the mammary gland.

The protein of colostrum is characteristic since the greatest part of it will coagulate. Acid coagulation occurs very easily and the curd is tough.

The colostral fat is richer in oleic acid than is milk fat and as a result the iodin index is considerably higher.[5]

HUMAN MILK

Bacteriology.—Since the infant takes the milk directly into the mouth from the breasts, only such organisms as are in the breast gland itself can get into the milk.[6]

These investigations show that the milk of healthy women, whose breasts are free from pathologic conditions, contains microorganisms in the majority of instances. In the majority of cases the organism is staphylococcus aureus. Most investigators believe

[1] Deville: Arch. internat. de méd. leg., 1913, iv, 60.

[2] Steele: Arch. Pediat., 1910, xxvii, 32.

[3] Thomas: Vortr. geh. a. d. Vereinig, Sachs-Thuring; Kinderarzte in Dresden, 1913, Ref.; Ztschr. f. Kinderh. (Ref.), 1913, vi, 28.

[4] Bauer: Deutsch, med. Wochenschr., 1909, xxxv, 1657.

[5] Engel: In Sommerfeld's Handbuch der Milchkunde, Wiesbaden, 1909, p. 810.

[6] Escherich: Fortschr. d. Med., 1885, iii, 231; Cohn and Newmann: Virchow's Arch. f. path. Anat., 1891, cxxvi, 391; Palleske: Virchow's Arch., 1892, cxxx, 185; Honigmann: Ztschr. f. Hyg. u. Infectionskr., 1893, xiv, 207; Ringel: München. med. Wchnschr., 1893, xl, 513; Genoud: Sur la présence du staphylocoque dans la lait des accouchées bien portantes, Thèse de Lyon, 1894; Knochenstiern: Hyg. Rundschau, 1894, iv, 231; Halleur: Inaug. Diss. Leipzig, 1893; Brumm: Arch. f. Gynaecol., 1886, xxvii, 461; Merit: Thèse de Paris, 1887; Johanessen: Jahrb. f. Kinderh., 1895, xxxix, 398; Roeper: Inaug. Diss., Marburg, 1896; Koestlin: Arch. f. Gynaecol., 1897, liii, 201.

that the bacteria get in from the outside. Evidence in favor of this view is the fact that it is easier to demonstrate these organisms in the first part of the milk drawn than in the last part. Finally when the milk is withdrawn gently drop by drop, rather than strongly and rapidly, many tests are sterile. This fact makes it seem probable that the rough handling of the breast gland during nursing or by massage dislodges the bacteria and forces them into the milk.

Syphilitic lesions have been induced in rabbits by inoculating them with milk from syphilitic women, although the milk was sterile and no spirochaeta pallida were found in the milk.[1]

Typhoid bacilli have been found by Lawrence [2] in the milk of a woman suffering with typhoid fever.

Under normal conditions no ill effects are caused by the bacteria in human milk. The children who take this milk thrive in spite of the presence of bacteria in the first portion of the milk. The bacteria in human milk have no pathologic significance for the healthy infant. It has been shown that this is not the fact in babies with disturbances of digestion. Moro [3] has recently ascribed to the staphylococci in human milk an etiologic rôle in the dyspeptic conditions of breast-fed infants.

Appearance, Smell and Taste.—Human milk has the same appearance as cow's milk, except that, when it is cooled, small white flakes are apt to stick to the side of the bottle. These flakes disappear when the milk is warmed. It has no odor and its taste is sweet. When the color becomes yellower than that of cow's milk it is due to an increased percentage of fat.

Microscopic Appearance.—It contains many minute fat droplets which are held in a state of permanent emulsion by the solution in which they are suspended. It may contain a few leukocytes and epithelial cells. The ultramicroscope shows numerous fine particles in lively molecular motion between the fat droplets. These particles are less numerous than in cow's milk. They are composed of casein.[4]

Specific Gravity.—The specific gravity averages between 1.030 and 1.032. It may fall as low as 1.020 and rise as high as 1.036.[5]

[1] Uhlenhuth and Mulzer: Deutsch. med. Wochenschr., 1913, xxxix, No. 19.

[2] Lawrence: Boston Med. and Surg. Jour., 1909, clxi, 152.

[3] Moro: Jahrb. f. Kinderh., lii, 542.

[4] Alexander and Bullowa: Jour. Am. Med. Assn., 1910, lv, 1196; Mauntner: Arch. f. Kinderh., 1908–9, xlix, 29; Kreidl and Neumann: Pflüger's Arch., 1908, cxxiii, 523.

[5] Engel: In Sommerfeld's Handbuch der Milchkunde, Weisbaden, 1909, p. 774; Konig: Note 9.

Reaction.—The reaction of human milk is amphoteric. It is acid to phenolphthalein and alkaline to litmus. The reason for the double reaction is the fact that the milk contains both mono- and diphosphates. The former are weakly acid, while the latter react as a base. If 10 c. c. of human milk are titrated with decinormal acid and litmus, it will require about 0.9 to 1.25 N/10 acid to neutralize them; it requires 0.12 to 0.55 N/10 NaOH with phenolphthalein. One hundred cubic centimeters of milk require 60 to 80 c. c. N/10 HC1 to show the Gunzburg reaction.[1] The alkaline reaction of human milk is relatively stronger than the acid reaction, but the absolute amount of acidity and alkalinity are less than in cow's milk. The electrical measurement of human milk as well as of all other milks is neutral.[2]

Quantity.—The amount of human milk secreted by healthy mothers depends on the demands of the infant. The twenty-four-hour amount of milk, therefore, depends in large part on the weight and strength of the infant. It is obvious that what might be a normal amount for one infant would be abnormal for another, and for this reason averages are of no greater value than the average weight of the infant. The figures representing the amount of milk taken by the infant are obtained by weighing either the mother or the baby before and after each nursing. The table of Cramer's [3] figures shows the difference between the secretion of milk in primiparæ and multiparæ:

TABLE 20

TWENTY-FOUR HOUR AMOUNT OF MILK IN GRAMS

Day postpartum	1	2	3	4	5	6	7	8	9	10
Nine babies of primiparæ; average birth weight, 3,290 gm.	4	78	183	199	236	299	303	274	362	384
Seven babies of multiparæ; average birth weight, 3,348 gm.	6	129	238	324	344	324	361	365	384	415

Table 21 from Czerny and Keller [4] gives the figures that Feer calculated as the amount of milk babies of the average weight

[1] Courant: Pflüger's Arch., 1891, i, 109; Escherich: Verhandl. d. Versamml. d. Ges. f. Kinderh., Heidelberg, 1889, 109.

[2] Foa: Soc. Biol., 1905, lviii, 863; 1905, lix, 51.

[3] Cramer: Klin. Beitr. z. Frage der kunstlichen Ernährung des Neugeborenen. Inaug. Diss., Breslau, 1896. Taken from Czerny and Keller, Des Kindes, etc., Vol. 1, p. 356.

[4] Czerny and Keller: i, 353.

(Camerer's figures) would take in a day. They do not differ much from those given by Camerer.

Czerny and Keller [1] (Vol I, Chapter 18) should be consulted for a more detailed discussion of the amounts of breast milk secreted by the average woman. These amounts may be increased when a woman nurses two or more babies as does the wet-nurse. A wet-nurse [2] increased the amount of milk secreted in ten days from 720 grams when she nursed two infants to 1,750 grams when she nursed five infants.

TABLE 21

AVERAGE DAILY AMOUNT OF MILK DRAWN BY A BABY (FROM CZERNY AND KELLER)

Age in weeks	*Average weight of breast-fed babies according to Camerer, gm.*	*The calculated day's amount of milk, gm.*	*Age in weeks*	*Average weight of breast-fed babies according to Camerer, gm.*	*The calculated day's amount of milk, gm.*
1	3,410	291	14	5,745	870
2	3,550	549	15	5,950	878
3	3,690	590	16	6,150	893
4	3,980	652	17	6,350	902
5	4,115	687	18	6,405	911
6	4,260	736	19	6,570	928
7	4,495	785	20	6,740	947
8	4,685	804	21	6,885	956
9	4,915	815	22	7,000	958
10	5,055	800	23	7,150	970
11	5,285	808	24	7,285	980
12	5,455	828	25	7,405	990
13	5,615	852	26	7,500	1,000

Coagulation.—The recent observations with the ultramicroscope [2] have helped to explain the coagulation of milk. The essential differences in the coagulation of human and cow's milk are as follows: The casein of human milk is precipitated with greater difficulty with acids or salts and it does not coagulate uniformly after the addition of rennet; and, lastly, the clot that forms does not appear in such large coarse masses as the casein from cow's milk, but is more loose and flocculent.

[1] Czerny and Keller: i, 353.
[2] Czerny and Keller: i, 458.

(a) *Precipitation with Acids.*—Bienenfeld [1] showed that there is a certain acidity at which the casein is precipitated most easily. When lactic acid is used, this point is between 22 and 24 c. c. N/10 acid to 100 c. c. of milk. If the milk is made acid up to this point and warmed to 40 C. (104 F.) the casein precipitates out of the solution. If the milk is diluted five times, the precipitation is accelerated. A watery, clear whey is left behind. Engel [2] showed that this was also true of strong acids (20 to 30 c. c. N/10 acid to 100 c. c. milk), but the best results were only seen at a certain degree of acidity. Slight variations above or below this point did not give good results. When acetic acid is used, more is necessary, *i. e.*, 60 to 160 c. c. N/10 of the acid to 100 c. c. milk.

(b) *Rennin Coagulation.*—If a neutral solution of rennet is added to milk there is no macroscopic or microscopic change until the milk is acidified, but the ultramicroscope shows that the rennin ferment acts also in neutral solutions.[3] Although human milk does not coagulate uniformly with rennin, it has been shown that it is capable of coagulation.[4] After human milk has been frozen several days and then rennin plus acid are added, there is a definite coagulation. Human milk does not coagulate with rennin alone. Two factors may explain the diminished coagulability of human milk, viz., the relative alkalinity of the milk and its low calcium content.[5] Engel [6] saw a better precipitation when he diluted the milk with water that contained calcium, than when he used distilled water. The coagulation is also facilitated, if the milk is kept cold for several hours.[7]

The precipitate is characteristic and is always in more or less fine curds, which are never as large as the curd from acidified cow's milk. The curds in undiluted milk are especially fine and can be seen only with the microscope. It is interesting that they do not sink to the bottom in milk from which the cream has not been removed, but rise to the top. In skimmed milk they may fall to the bottom.

(c) *The Difference between Acid and Rennin Coagulation.*—There is no macroscopic difference. The ultramicroscope shows that neutral solutions of rennin cause the casein, which was previously invisible, to become visible.[3] Acid must subsequently

[1] Bienenfeld: Biochem. Ztschr., 1907, vii, 262.
[2] Engel: *Loc. cit.*, Note *19, p. 775.*
[3] Kreidl and Neumann: (See note 4, 97).
[4] Schlossmann and St. Engel: Oppenheimer's Handbuch, etc., iii, 430.
[5] Fuld and Wohlgemuth: Biochem. Ztschr., 1907, v. 119.
[6] Engel: Biochem. Ztschr., 1908, xiii, 89.
[7] L. F. Meyers: Verhandl. d. ges. f. Kinderh., Stuttgart, 1906, p. 122.

be added to cause a definite precipitation. The curds from acid plus rennin coagulation are not so easily dissolved as those from acid coagulation alone. Chemically there results from rennin coagulation a casein body, which is rich in calcium—paracasein. The whey which results from rennin and acid coagulation, contains less nitrogen than that from acid precipitation.[1]

Chemical Composition.—The principal components of milk are fat, lactose, proteins, salts and water. It also contains small amounts of extractives and citric acid as well as certain unknown substances.

Nitrogenous Bodies.—1. *Total Nitrogen.* The total nitrogen in milk is usually determined by the Kjeldahl method and this figure is multiplied by the factor 6.25, or 6.37, to give the albumin content. This method is, however, not free from error, because there are other bodies that contain nitrogen and yet are not classed among the albumins. These, according to various authors,[2] may make up between 17 and 20% of the total nitrogen. Taking this fact into consideration and deducting the non-albuminous nitrogen from the total nitrogen, there is, according to Camerer and Söldner, 1.04% of albumin in human milk. The average figures as to the total amount of nitrogen in 100 c. c. of milk at different stages of lactation are [3] as shown in the following table:

TABLE 22

TOTAL NITROGEN IN 100 C. C. MILK AT DIFFERENT STAGES IN LACTATION (SCHLOSSMANN)

Days post partum	*Total nitrogen*	*Nitrogen factor ×6.25*
9 to 10	0.29	1.81
11 to 20	0.29	1.81
21 to 30	0.31	1.94
31 to 40	0.24	1.50
41 to 50	0.28	1.75
51 to 60	0.25	1.56
61 to 70	0.23	1.44
71 to 100	0.20	1.25
101 to 140	0.20	1.25
141 to 200	0.207	1.29
Over 200	0.21	1.31

[1] Engel: In Sommerfeld's Handbuch der Milchkunde, Wiesbaden, 1909, p. 810.

[2] Camerer and Söldner: Ztschr. f. Biol., N. F., 1898, xviii, 277; Rietschl: Jahrb. f. Kinderh., lxiv, 125.

[3] Schlossmann: Arch. f. Kinderh., 1900, xxx, 324; 1902, xxxiii, 187.

The amount of albumin in the milk varies during the same day and even during a single nursing. These variations are, however, not of any great significance. The next table shows the variations in the milk of eight wet-nurses during a single day, samples having been taken from each of the nursings. The individual variations are so slight, however, that if the average for the day is taken and compared with the average for the stage of lactation, the same diminution in the amount of albuminous material during the progress of lactation is seen as in the table.[1] (The factor of nitrogen times 6.25 was used.)

TABLE 23

VARIATION IN THE MILK OF EIGHT WET-NURSES DURING A SINGLE DAY (ENGEL)

Age of nurse, years	*Day of lactation*	*Am't, c. c.*	5	*Morning* 9	12	3	*Afternoon* 6	10	*Avg.*
16	45	2,000	1.386	1.458	1.305	1.324	1.306	1.279	1.344
19	58	1,500	1.163	1.118	0.956	1.073	1.163	1.127	1.100
29	60	2,200	1.149	1.154	1.395	1.261	1.136	1.161	1.208
25	70	2,700	1.314	1.243	1.127	1.216	1.046	1.064	1.170
23	72	3,000	1.207	1.234	1.154	1.315	1.154	1.163	1.204
21	100	3,300	1.135	1.117	1.127	1.154	1.243	1.028	1.119
19	130	1,800	0.492	1.019	1.127	1.064	0.903	1.082	0.948
25	140	2,200	1.082	1.064	1.100	0.939	1.082	1.064	1.036
								Avg.	1.141

2. *Residual Nitrogen.*—The residual nitrogen is that fraction of the nitrogen which is found in the filtrate after the precipitation of the albumins and which does not give the reactions for protein.[2] Part of this residual nitrogen is supposed to be in the form of urea (50% or more) and another part in an amino-acid or a peptid-like body.[3] There is less of it in cow's milk than in human milk. The significance of these bodies is unknown.

The milk and blood serum of a 21-year-old primipara with chronic nephritis (urinary albumin=0.3%) were simultaneously examined on two occasions. The residual nitrogen of the serum was 5.33% and 7.43% of the total nitrogen; that of the milk was

[1] Engel: In Sommerfeld's Handbuch der Milchkunde, Wiesbaden, 1909, p. 810.

[2] Munk: Virchow's Arch. f. path. Anat., 1893, 134, 501. (First studied this body.)

[3] Rietschel: Jahrb. f. Kinderh., lxiv, 125.

27.19% and 32.88%, both being much above the normal. Urea was considered to be the probable cause of this increased amount.[1]

3. *The Albuminous Bodies.*—Human milk contains two groups of albuminous bodies: (1) *casein,* which is insoluble in water, and (2) *lactalbumin* and *globulin,* which are soluble in water. The separation of these bodies in human milk is more difficult than in cow's milk, because of the difficulty in precipitating the casein. There is, on this account, much opportunity for future investigations to add to our knowledge of the proteins of human milk. The figures which are most generally adopted are those of Schlossmann,[2] who found that about 41% of the total nitrogen is in the form of casein. From 15 to 20 % of the total nitrogen may, however, be residual nitrogen (see above). If this amount is deducted only 44 to 39% are left to be divided between the lactalbumin and globulin. Ciccarelli [3] found that the relation of casein to lactalbumin in human milk was 26.9–37.9 to 62.1–73.1. These figures show that there is considerable variation in the quantities of these bodies even in human milk. The following figures represent what may be considered averages. The total protein is divided as follows:

Casein, 41%; lactalbumin and globulin, 44 to 39%; residual nitrogen, 15 to 20%.

Opalisin was described in 1888 by Wroblewski [4] as a new albumin which is present in very small amounts in cow's milk and in large amount in mare's milk. It is also present in human milk. Very little is known about this body.

COMPARISON OF PROTEINS OF HUMAN AND COW'S MILK

Casein.—The facts that it is difficult to precipitate casein from human milk and that it takes large amounts of milk to obtain a sufficient quantity of casein for analysis have retarded our knowledge of the subject. For this reason more is known about cow casein than human casein.

Casein is insoluble in water, but is soluble in water to which alkalies have been added. If acid is added to this alkaline solution, the casein will again be precipitated. If enough alkali is subsequently added it will again go into solution. The analysis of casein is shown in table 24.

[1] St. Engel and Murschauser: Ztschr. f. physiol. Chem., 1911, lxxiii, 101.
[2] Rietschel: Jahrb. f. Kinderh., lxiv, 125.
[3] Ciccarelli: La Pediatria, 1908, vi, 12.
[4] Wroblewski: Ztschr. f. Physiol. Chem., 1898–99, xxvi, 308.

TABLE 24

ANALYSIS OF CASEIN (FROM ENGEL)

Author	*C*	*H*	*S*	*P*	*N*
Wroblewski [1]	52.24	7.32	1.12	0.68	14.97
Bergell and Langstein [2] ..	53.01	7.14	0.71	0.25	14.60
	52.63	6.94	0.85	0.27	14.34

The sulphur content of cow and human casein is as follows:

Cow Casein		*Human Casein*	
Liebig [3]	Hempel [3]	Liebig	Hempel
0.723	0.723	0.094–1.079	1.072

According to these figures there is more sulphur in human than in cow's milk. They correspond closer to Wroblewski's figures than to those of Bergell and Langstein. It is still a disputed question whether the casein from different kinds of milk is identical or whether there are several different caseins. Recently Langstein and Edelstein found that the phosphorus content of human milk was 0.22 to 0.28% and that of cow's milk 0.85 to 0.87% and concluded that this was evidence that the two caseins were different compounds.

Bordet [4] showed that repeated injections of cow's milk into other animals caused a body to appear in the blood which precipitated the albuminous bodies of cow's milk and made them coagulate. Wasserman [5] and others went a step further and showed that the blood serum of animals sensitized to cow's milk would precipitate the albuminous bodies in cow's milk, but would not precipitate those in human milk or the milk of other animals, and that the blood serum of animals sensitized to human milk precipitates the albuminous bodies in human milk and does not precipitate them in the milk of other animals. In other words, the blood serum of an animal may be sensitized to the albumins of a certain species of animal and react specifically to that species. These experiments can leave no doubt that the proteins of different animals are different.

Further investigations showed that casein, lactalbumin and

[1] Wroblewski: Ztschr. f. Physiol. Chem. 1898–99, xxvi, 308.

[2] Bergell and Langstein: Jahrb. f. Kinderh., 1908, lxviii, 568.

[3] Engel: In Sommerfeld's Handbuch der Milchkunde, Wiesbaden, 1909, p. 810.

[4] Bordet: Ann. de l'Inst. Pasteur, 1899, xiii, 240.

[5] Wasserman: Verhandl. des 18 Congr. f. inn. Med., 1900, p. 501.

globulin could be differentiated from one another by complement fixation and anaphylaxis experiments.[1] Milks of animals of one species can, therefore, be differentiated from the milk of animals of another species and the casein, globulin and lactalbumin of the same milk can be differentiated one from the other.

Fat.—The fat in human milk is in a very fine emulsion. When the number of drops are counted in a counting chamber there are always more in human milk than in cow's milk.[2] The fat globules in human milk measure between 0.001 and 0.02 mm., while those in cow's milk measure 0.0016 to 0.01 mm.[3] Since the measurements given above show that the fat drops in human milk may be of greater diameter than those in cow's milk, it seems inconsistent that there should be a larger number in the former than in the latter. The explanation must be that the majority of fat drops in human milk are small and measure about 0.001 mm., while the majority of those in cow's milk must be closer to the upper limit and measure nearly 0.01 mm.

Percentage and Quantity of Fat.—The figures as to the percentage of fat and the total amount of fat in human milk vary considerably according to the various investigators and the methods they pursue in obtaining their material. Engel's [4] monograph on human milk gives the most complete summary of the knowledge of this subject and is quoted freely in the following paragraphs. The percentage of fat is smallest at the beginning of nursing and largest at the end of nursing, the steepness of the curve depending on the total amount of milk taken at a nursing. When a small amount is taken, there is a sharp rise in the percentage of fat, and when there is a large amount of milk taken, there is a more gradual rise. Although the percentage may increase regularly throughout the nursing, this is by no means the rule. The three curves taken from Engel give examples of how the percentages of fat may increase (see Chart).

The percentage of fat in the first milk drawn varies between 1 and 3 % and that in the last milk taken between 6 and 10%. These figures may occasionally be even higher. There are cases on record in which there was more fat in the first part of the milk than in

[1] Bauer and St. Engel: Biochem. Ztschr., 1911, xxxi, 46; Kleinschmidt: Monatschr. f. Kinderh., 1911–1912, x, 402.

[2] Czerny and Keller: Des Kindes; Ernährung, Ernährungsstörungen, und Ernährungstherapie, Leipzig and Wein, 1906, 1, 407.

[3] Leaves: Ztschr. f. physiol. Chem., 1894, xix, 369; Ruppel: Ztschr. f. Biol., 1894, xxi, 1.

[4] Engel: In Sommerfeld's Handbuch der Milchkunde, Wiesbaden, 1909, p. 810.

the last part and the curve is the reverse of the one just described.[1]

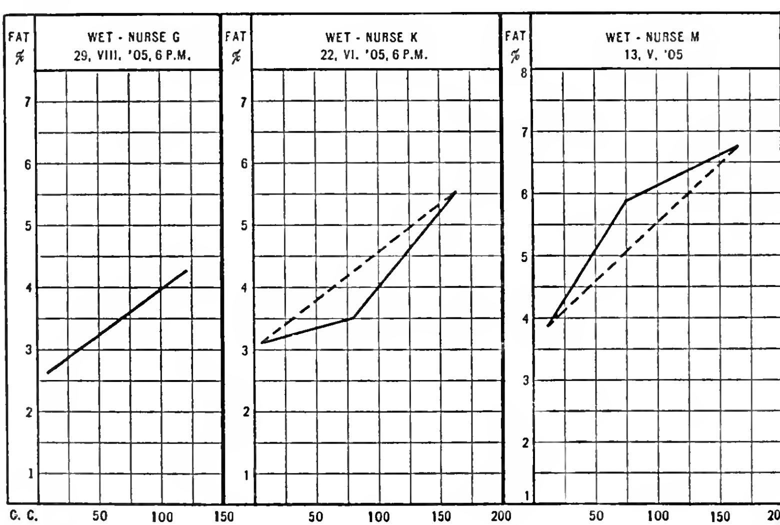
In pathological conditions the extremes of the percentage of fat are 0.1% [2] and 13.7%.[3]

The average fat content of the milk of ten wet-nurses (German) examined by Engel was 4.5%, and of 119 women (Russian) examined by Skvortzov,[4] 3%. The amount of fat in the milk of the same women may vary from 25 to 100% in the same day at different nursings. When the intervals of emptying the breasts are long there is more milk and less fat. When all the milk of a woman is collected each day the average daily percentage is constant. This is true even if the total amount of milk is considerably increased.

Quality of Fat.—When fat is separated from human milk by dissolving it in ether, it forms a yellowish-white mass similar, at room temperature, to butter.

CHART IV

Chart from Engel.—The heavy black line indicates the increase in the per cent of fat when the milk is examined at frequent intervals during a single nursing.



[1] Engel: Arch. f. Kinderh., 1906, xliii, 181.
[2] Moll: Arch. f. Kinderh., 1908, xlviii, 161.
[3] Engel: Arch. f. Kinderh., 1906, xliii, 194.
[4] Skvortzov: Russki Vratch ii, p. 1392; Ref. Chem. Abstracts, 1913, vii, No. 18.

The melting point of human milk is between 30 and 34 C.

The solidifying point is between 19 and 22.5 C.

The specific gravity at 15 C. is 0.97.[1]

The fat of human milk is relatively poor in volatile fatty acids when compared with cow's milk.

Volatile fatty acid, human milk, 2.5% of total fat.

Volatile fatty acid in cow's milk, 27.0% of total fat.

Among the volatile fatty acids have been demonstrated butyric, capronic, caprinic and caprylic acids. One-half of the non-volatile fatty acids are oleic acid, while among the solid fatty acids myristic and palmitic acids are found to be more abundant than stearic acid.[2] The large amount of oleic acid explains the relatively lower melting point and higher iodin value of human milk than of cow's milk.

The iodin value of the fat in human milk varies within fairly wide limits, but is usually found at about 45. There are women in whom it sinks to 32 and others in whom it is as high as 50.[3] Certain observations go to show that the iodin value is in part dependent on the food. Goose fat, linseed oil [4] and iodized fats [5] have been demonstrated to pass from the food into the milk.

Lactose.—Lactose, or milk sugar, is found only in the milk of animals. It is essentially the same in the milk of the woman, the cow, ass, rabbit, dog and horse.[6] There is evidence [7] which suggests strongly that lactose is formed from the dextrose in the blood. The quantity of lactose varies the least of all the elements of human milk. The amount of lactose in human milk is almost twice that in cow's milk, being on the average about 7%. The lowest percentage which has been found is 4.22 [8] and the highest 10.9%.[9] A few instances have been recorded in which the addition of sugar to the diet of the mother has increased the amount of sugar in the milk. This is, however, by no means the rule.[10]

[1] Ruppel: Ztschr. f. Biol., 1894, xxxi, 1; Laves: Ztschr. f. physiol. chem., 1894, xix, 369; Sauvaitre: Ref., Malys. Jahresb. d. Tierchemie, 1903, xxxiii, 324.

[2] Hammersten: English translation Text-book Physiological Chemistry, N. Y., 1909, p. 530.

[3] Engel: In Sommerfeld's Handbuch der Milchkunde, Wiesbaden, 1909.

[4] Thiemich: Monatschr. f. Geburtsh. u. Gynäk., 1899, ix, 515.

[5] Bendix: Deutsch. med. Wochenschr., 1898, xxiv, 223.

[6] Deniges: Contribution a l'étude des lactoses, Paris, 1892; Bonmartini: Rev. gén. du lait, 1906, ii, No. 1.

[7] Porcher: Biochem. Ztschr., 1909–10, xxiii, 370; Paton and Cathcart: Jour. of Physiol., 1911, xlii, 179.

[8] Pfeiffer: Verh. II, Versaml. d. Gesselsch. f. Kinderh., Wien, 1894, p. 131.

[9] Schlossmann: Arch. f. Kinderh., 1900, xxx, 324.

[10] Lust: Monatschr. f. Kinderh., 1913, xi, 236.

Lecithin.—It has been estimated that 100 c. c. of human milk contains 0.058 gm. of lecithin.[1] The question has been raised, however, whether the body that was quantitated as lecithin was not a result of the breaking down of some of the phosphorus-containing bodies by the chemical manipulations during the investigation.

Nuclein.—There is considerable debate as to whether human milk contains nuclein or not. Three cases which were examined [2] showed an average per cent during one year as follows: 0.1302, 0.1339 and 0.1305. The amount was inversely proportional to the quantity of the milk.

Salts.—Total Ash: The average amount of ash in human milk is about 0.21%.[3] The amount of ash diminishes during the course of lactation just as does that of the protein. This is shown in the following from Camerer and Söldner:

Days postpartum	*Per cent of ash*
8– 11 days	0.28
29– 40 days	0.22
60–140 days	0.19
170 days and later	0.18

The following table shows the percentage of the various salts in human milk to 100 parts of ash.

TABLE 25

PERCENTAGE OF SALTS IN HUMAN MILK TO 100 PARTS OF ASH (FROM ENGEL AND SCHLOSS)

	Bunge [4]	*Blackhans and Kronheim* [5]		*de Lange* [6]	*Schloss* [7]
	I	I	II		
K_2O	32.14	33.74	27.33	19.9	28.77
Na_2O	11.75	11.91	15.88	29.6	10.26
CaO	15.67	17.36	15.52	12.9	20.44
MgO	3.99	3.17	2.13	2.9	4.66
Fe_2O_3	0.27	0.63	1.75	0.25	
P_2O_5	21.42	14.79	11.75	17.9	22.0
CL	20.35	15.47	23.93	21.3	16.61

[1] Burow: Ztschr. f. Physiol. Chem., 1900, xxx, 506.
[2] Valenti: Chem. Zentralbl., 1909, i, 93.
[3] Camerer and Söldner: See Note 5, p. 94; Pfeiffer: Verh. d. gesellsch. f. Kinderh., Wien, 1894, p. 126.
[4] Bunge: Ztschr. f. Biol., 1874, x, 316.
[5] Bericht d. landw. Inst. d. Univ. Königsberg, v. 61.
[6] De Lange, Cornelia: Ztschr. f. Biol., 1900, xl, 527.
[7] Schloss: Ueber Sauglingsernährung, Berlin, 1912, p. 58.

The composition of the ash of human milk is, according to Söldner [1] as shown in table 26.

TABLE 26

COMPOSITION OF ASH OF HUMAN MILK (FROM ENGEL)

	100 gm. milk contains, milligrams			100 gm. ash contains, milligrams		
	First milk	*End milk*	*Average*	*First milk*	*End milk*	*Average*
K_2O	100.8	63.4	88.4	32.5	31.9	32.4
Na_2O	44.8	17.6	35.7	14.5	8.9	13.1
CaO	37.6	38.1	37.8	12.1	19.2	13.9
MgO	5.4	5.2	5.3	1.7	2.6	1.9
Fe_2O_3	0.22	0.12	0.2	0.07	0.06	0.07
P_2O_5	32.10	28.8	31.0	10.40	14.50	11.40
SO_3	9.6	7.2	9.0	3.1	3.6	3.3
Cl	71.7	34.2	59.1	23.1	17.3	21.7

These figures show that the ash varies in amount, as well as other milk components, according to whether the sample of milk is taken at the beginning or at the end of nursing. It is obviously just as necessary to obtain milk under the same conditions and with the same precautions when the salts are to be investigated as when the other food components are to be studied.

Calcium.—A large number of analyses show wide individual variations between 0.03 and 0.08%, with an average of 0.042 to 0.044%. The daily variations may amount to as much as 0.02%. The calcium content decreases as the period of lactation progresses. The amount of calcium cannot be increased by feeding the mother with calcium salts.[2]

Iron.—Friedjung [3] found from 3.52 to 7.21 mg. iron in a liter of human milk. This gives an average of 5.09 mg. This figure is somewhat higher than those given by Camerer and Söldner [4] and Bahrdt and Edelstein,[5] who found between 1.215 and 2.93 mg. per liter. The iron content of the milk is dependent on the general condition of the woman. It is higher in healthy individuals and

[1] Söldner: From Sommerfeld's Handbuch, etc., p. 800.

[2] Bahrdt and Edelstein: Jahrb. f. Kinderh., 1910, lxxii, 16; Schabad: Jahrb. f. Kinderh., 1911, lxxiv, 511.

[3] Friedjung: Arch. f. Kinderh., 1901, xxxii, 58; Jolles and Friedjung: Arch. f. exper. Path. u. Pharm., 1901, xlvi, 247 (entire literature to date).

[4] Camerer and Söldner: Ztschr. f. Biol., 1900, xxxix, 190; 1903, xliv, 71; 1905, xlvi, 371.

[5] Bahrdt and Edelstein: Ztschr. f. Kinderh., 1910, l, 182.

lower in those under par. A regular decrease in the amount of iron during lactation has not been demonstrated. Neither have investigations of the iron content of the milk in pathologic conditions of either the mother or the baby given any figures of clinical significance.

Chlorids.—Freund[1] found that 1,000 c. c. of the milk of the same woman contained, on four successive days: 0.488, 0.498, 0.433 and 0.456 NaCl. Bunge obtained similar results.

Phosphorus.—There is a great difference in the form in which phosphorus is present in human and in cow's milk. Three-quarters of that in human milk is in organic combination, while only one-quarter of the phosphorus in cow's milk is in organic combination. The phosphorus which is in organic combination is considered by many to be in the form of lecithin and nucleon, which are present in larger amounts in human than in cow's milk[2] (see lecithin and nucleon); 41.5% of the total phosphorus in human milk is in the form of nucleon phosphorus and only 6% in cow's milk.[2] Because of the larger amount of casein and calcium phosphate which it contains, cow's milk is much richer in phosphorus than human milk. The relation of P_2O_5 to N is 1:54 in human milk, and 1:27 in cow's milk.[3] Keller[4] found that one liter of milk contained of P_2O_5

Grams P_2O_5;			
0.40	The mixed milk of different wet-nurses.	0.386	The same woman.
0.44		0.382	
0.377			
0.452			
0.353			

Sikes[5] gives 0.297 P_2O_5 to the liter as an average of figures in the first three weeks of life. The amount varies between 0.14 and 0.522. Schlossmann[3] gives as an average 0.461 P_2O_5 per liter. The phosphorus content of the milk depends in good part on the casein content of the milk.

Citric Acid.—The average amount of citric acid in human milk is 0.05%.[6]

[1] Freund: Chlor. und Stickstof in Sauglings organisms, Jahrb. f. Kinderh., 1898, N. F., xlviii, 137.

[2] Siegfried: Ztschr. f. Phys. Chem., 1897, xxii, 575; Whittmaack: Ztschr. f. physiol. Chem., 1897, xxii, 567; Burow: Ztschr. physiol. Chem., 1900, xxx, 495.

[3] Schlossmann: Arch. f. Kinderh., 1905, xl, 1.

[4] Keller: Arch. f. Kinderh., 1900, xxix, 1.

[5] Sikes: Jour. Physiol., 1906, xxxiv, 464.

[6] Scheibe: Quoted by Engel. See note 5, p. 96.

Caloric Value.—The caloric value of one liter of human milk is 782 calories.[1]

Unknown or Unidentified Substances.—Meigs and Marsh [2] report the presence of substances of unknown nature which contain little or no nitrogen and are soluble in alcohol and ether. Human milk immediately after the colostrum stage contains 1% of these unknown substances, while milk from the middle period of lactation contains about 0.5%; cow's milk from the middle period of lactation contains about 0.3% of these substances.

Viscosity.—There is in most cases a regular decrease in the viscosity of milk during the first twenty-four hours postpartum. There is no difference between the viscosity in normal or abnormal cases then or later. The *electrical conductivity* is almost always increased in abnormal cases. This increase is least when there is albuminuria and greatest when the supply of milk is scanty. There is a regular decrease in the electrical conductivity during the first week postpartum.[3] The degree of viscosity depends on the amount of solids in the milk especially of casein.[4]

VARIATIONS IN THE COMPOSITION OF HUMAN MILK

Table 27, page 112, shows the lowest and highest figures given by various authors. These figures show that the variations in the percentage of fat are the greatest, but that there are considerable differences in the percentages of the other components of human milk. There are no figures in literature in which the percentages of all components are high or all low. Usually, when one component is increased, another is diminished.

The average composition of human milk is usually given as follows: Fat, 4%; lactose, 7%; protein, 1.50%; (casein 42%, filterable nitrogen [including lactalbumin, globulin and unknown bodies 58%); salts, 0.21%.

The previous tables show that human milk may vary widely in its composition from these figures and still be normal.

Influence of Food on Quantity and Composition of Milk.—The effect of food on the chemical composition of milk has been investigated and, with the exception of the work done on fats, does not warrant any conclusions. The fat in the milk may diminish

[1] Schlossmann: Archiv. f. Kinderh., 1900, xxx, 288.
[2] Meigs and Marsh: Jour. of Biol. Chem., xvi, No. 1.
[3] Polenaar and Phillipo: Ztschr. f. Pathol., ix, 138.
[4] Oertel: Dissertation, Leipzig, 1908, Ref. Arch. f. Kinderh., 1909, li, 282.

TABLE 27

VARIATIONS IN COMPOSITION OF HUMAN MILK (FROM CZERNY AND KELLER)

	Fat, per cent.	*Sugar, per cent.*	*Protein,* per cent.*	*Ash, per cent.*	*Solids, per cent.*
Pfeiffer [1]	0.75–9.05	4.22– 7.65	1.049–3.04	0.104–0.446	8.23–15.559
Johannessen and Wang [2] .	2.7 –4.6	5.9 – 7.8	0.9 –1.3	....	
V. and J. S. Adriance [3] . .	1.31–7.61	5.35– 7.95	0.23 –2.60	0.09 –0.28	9.19–15.31
Guirand [4]	1.75–6.18	5.7 – 7.7	0.85 –1.4	0.10 –0.27	11.2 –16.3
Camerer and Söldner [5] ...	1.28–5.77	5.35– 7.52	0.82 –1.86	0.11 –0.36	9.41–14.11
Schlossmann [6] .	1.65–9.46	5.2 –10.90	0.56 –3.4		

* Nitrogen times 6.25.

when the mother is underfed.[7] If more fat is given in the diet of such an underfed woman, the fat in the milk will increase up to a certain point. If, however, large amounts of fat are given to women who already have sufficient quantities of fat in the food, there is only a temporary increase in the fat in the milk in spite of the excessive fat in the diet.[8] Czerny and Keller [9] conclude that the milk of nursing mothers cannot be permanently influenced by the food, except in those instances in which they do not get sufficient food, *i. e.*, when they are partially starved. The quantity of the milk cannot be increased at will by increasing the amount of food or drink. There are a few instances on record in which the addition of sugar to the diet of a nursing woman has increased the amount of sugar in the milk. Such an increase is, however, by no means the rule (see lactose).

GALACTAGOGUES

Schafer and MacKenzie [10] found that the posterior lobe of the pituitary body of the ox and the corpus luteum of sheep both act

[1] Pfeiffer: Verhandl. d. II Vers. d. Gesellsch f. Kinderh. in Wien, 1894, p. 131.
[2] Johannessen and Wang: Ztschr. f. Physiol. Chem., 1898, xxiv, 499.
[3] Adriance, V. and J. S.: Arch. of Pediatrics, 1897, xiv, 27.
[4] Guirand: Thèse de Bordeaux, 1897.
[5] Camerer and Söldner: Ztschr. f. Biol., xli, N. F., 18, p. 280.
[6] Schlossmann: Arch. f. Kinderh., 1900, xxx, 324.
[7] Engel and Plaut: München. med. Wochenschr., 1906, liii, 1158.
[8] Albert: Ref. Malys. Jahresb. f. Thierchemie, 1899, xxix, 253; Henriques and Hansen: Jahresb. f. Thierchemie, 1899, xxix, 68.
[9] Czerny and Keller: Des Kindes; Ernährun[illegible]nährungsstörungen, und Ernährungstherapie, Leipzig and Wien, 1906, 1, [illegible]
[10] Schafer and MacKenzie: Proc. Roy. Soc., London (B), 1911, lxxiv, 16.

as galactogogues when injected into cats and dogs. Hammond [1] found that the injection of pituitary extract into lactating goats increased the amount of milk for twenty-four hours. The amount decreased below the normal during the next twenty-four hours, however, so that the average of the two days was the normal amount.[2] Gavin did not find the pituitary extract affected the quantity of milk in cows. MacKenzie and others [3] believe that the mammary gland can be stimulated by the posterior lobe of the pituitary body, the pineal body and the corpus luteum. The action of the former is supposed to be the most powerful. Inhibitory substances are said by some observers to be produced by the fetus, placenta, spleen, pancreas, adrenals and thyroid. Aschner and Grigori,[4] on the other hand, say that the pulp of placenta or of the fetus, or their watery extracts, cause a true secretion of milk in virgin animals, and that the body which causes this secretion is (contrary to Starling's contention) destroyed by alcohol and heat. Basch [5] reports that substances present in the placenta when injected into animals will bring back the secretion of milk after it has stopped. Wolf [6] injected milk into nursing women and found that there was an increase in the amount of milk secreted. Chatin and Rendu [7] repeated Wolf's work with eight women. They gave thirteen injections of milk with the result that in eight instances the curve of milk secretion remained stationary or became slightly lowered. In the five remaining instances, there was a slight increase in the amount of milk secreted after the injection of milk. This increase was, however, always in association with other factors, such as a change in the number of nursings, or a greater demand on the part of the infant. They believe that the latter were the cause of the increase and not the former.

There is much evidence to show that substances secreted in the ovary cause the growth of the breast glands at puberty. Cramer [8] believes that it has no influence on the hyperplasia of pregnancy, while Basch,[9] on the other hand, attributes the increase in size of the breast glands to a secretion in the ovary. The blood of a

[1] Hammond: Quart. Jour. Exper. Physiol., 1913, vi, 311.

[2] Gavin: Quart. Jour. Exper. Physiol., 1913, vi, 13.

[3] MacKenzie: Quart. Jour. Exper. Physiol., 1911, iv, 305; Ott and Scott: Therap. Gaz., 1911, xxxv, 689. (Experiments on goats.)

[4] Aschner and Grigori: Arch. Gyn., xciv, No. 3. (Guinea-pigs were used.)

[5] Basch: München. med. Wochenschr., 1911, lviii, 2266.

[6] Wolf: Zentralbl. f. Biochem. u. Biophys., 1913, xiv, 224.

[7] Chatin and Rendu [illegible]s méd., 1912, cxviii, 161.

[8] Cramer: München [illegible]. Wochenschr., 1909, lvi, 1521.

[9] Basch: München. Med. Wochenschr., 1911, lviii, 2266.

pregnant animal injected into a lactating animal has no influence on the secretion of milk.[1] Engel concludes that there are no artificial means of increasing the secretion of milk.

FOREIGN BODIES IN HUMAN MILK

Certain drugs have been proved to be excreted in human milk after they have been taken by the mother, but these are present only in traces. They are potassium iodid, sodium salicylate, antipyrin, mercury,[2] aspirin, calomel, arsenic, bromids,[3] urotropin,[4] and to a certain extent those bodies which are soluble in fat, such as the iodinized oils.[2]

Alcohol is found in human and cow's milk in minimal amounts after the ingestion of very large amounts, but not after the taking of small amounts.[5] It is possible that opium, in the form of morphin, and atropin may be excreted in human milk, since it has been shown that they go over into the milk of animals.[6] They have not as yet been found in human milk.

Salvarsan injected into the syphilitic mother is excreted in the milk and after such treatment the syphilitic suckling frequently shows remarkable improvement; in some instances the infant has suddenly died, so soon after the institution of treatment that death seemed to result from treatment.[7] It is evident that such treatment may not be entirely free from danger.

INFLUENCE OF VARIOUS PHYSIOLOGICAL AND PATHOLOGICAL CONDITIONS ON THE SECRETION OF MILK

Nervous Impressions.—"Fright, grief, passion, excessive sexual indulgence, or any great excitement may entirely arrest the secretion, or if not arrested the milk may be so altered in composition as to make the child actually ill." (Holt.) Although such phe-

[1] D'Errico: La Pediatria, Abstr. in Jahrb. f. Kinderh., 1910, xxii, 504.

[2] Engel: In Sommerfeld's Handbuch der Milchkunde, Wiesbaden, 1909, p. 810.

[3] Bucura: Ztschr. f. Exper. Path. u. Therap., 1907, iv, 398.

[4] Schmid and Schröter: Zentralbl. f. d. ges. Physiol. u. Path. Stoffwechsels, 1910, v. 129; Rieder: Monatschr. f. Kinderh., 1912, xi, 80.

[5] Voltz: Biochem. Ztschr., 1913, lii, 73.

[6] Czerny and Keller: Des Kindes; Ernährung, Ernährungsstörungen, und Ernährungstherapie, Leipzig and Wein, 1906, 1, 407.

[7] Jesionek: München. med. Wchnschr., 1911, lviii, 1169; Jeanselme: Ann. de gynéc. et d'obst., 1911, 2 Ser., viii, 394; Wolbarst: Am. Medicine, 1911, xvii, 486.

nomena have been observed clinically, there are no chemical observations which tell exactly what the chemical changes are under such circumstances, except those give by Rotch.[1]

Menstruation.—Rotch [1] gives the illustration, shown in the next table of a case in which the milk was examined during and after menstruation.

TABLE 28

EFFECT OF MENSTRUATION ON BREAST-MILK

	Fat	*Lactose*	*Protein*	*Salts*	*Water*
Second day of menstruation; child's stools loose. Per cent..............	1.37	6.10	2.78	0.15	89.60
Seven days after menstruation; bowels regular. Per cent..............	2.02	6.55	2.12	0.15	89.16
Forty days later; child gaining rapidly. Per cent ..	2.74	6.35	0.98	0.14	89.79

Bendix [2] examined the milk of eight women before, during and after menstruation. He concluded that such variations as he obtained were not outside of the normal physiological limits.

Uremia.—Finizio [3] studied the protein content of human milk and found that it increased only in nephritis and mild uremia (see residual nitrogen). Thiemich [4] concluded, after reviewing the literature, that this increase did not affect the nursing infant so long as the quantity of the milk and the health of the mother were normal.

Beriberi.—The milk of mothers with beriberi paralyzes the heart of frogs quicker than does Ringer's solution.[5] Clinically, such milk is dangerous for the infant and causes the disease. The poisons are probably toxins. They are excreted in greater quantities in the milk, if the mother is constipated.[6]

Bile.—Bile has been detected in the fat of the milk of a patient who developed jaundice after each confinement. The fat contained urobilin and small amounts of bilirubin, while there were no bile components in the aqueous liquid.[7]

[1] Rotch: Pediatrics, Philadelphia and London, 1901, p. 144.
[2] Bendix: Charité-Ann., 1898, xxiii, 412.
[3] Finizio: Pediatria, 1908, vi, 401.
[4] Thiemich: Monatschr. f. Geburtsch. u. Gynäk., viii, 521; ix, 504.
[5] Guerrero and Cavieres: Bull. Manila Med. Soc., 1912, iv, 167.
[6] Inagaki and Nakayama: Abstr. in Brit. Jour. Dis. Child., 1910, vii, 467.
[7] Marck: Pharm. Weekblad., 1907, xliv, 153.

DIFFERENTIATION OF HUMAN FROM OTHER MILKS

Umikoff's Reaction.—When 5 c. c. of milk are warmed on a water bath at 60 C. with 2.5 c. c. of a 10% solution of ammonium hydrate for from fifteen to twenty minutes, a reddish violet color appears if human milk is used, while there is no change with cow's milk.

Davidsohn's Reaction.—See fat-splitting ferment.

Moro's Reaction.[1]—Moro found that a 1% aqueous solution of neutral red turns human milk yellow and cow's milk purple. The addition of one drop of the stain to a teaspoonful of drawn breast-milk changes it to a reddish purple at once, if the milk has been kept too long and is unfit for use.

Bauer's Reaction.[2]—Bauer found that the addition of one drop of a 0.25% aqueous solution of neutral blue sulphate (Grubler) to from 2 to 3 c. c. of human milk turns the milk violet-blue. When added to cow's milk it turns it greenish-blue. When about five times as much ether is added and the mixture is shaken violently, the color is extracted from human milk but persists in cow's milk.

Tugendreich's Reaction.[3]—Equal amounts of a 1 to 2% aqueous solution of silver nitrate and milk are mixed, shaken and quickly boiled for three minutes. Human milk changes in color to coffee-brown or brownish-violet, while cow's milk does not.

FERMENTS (ENZYMES)

A great deal of importance has been attached to the ferments or enzymes of milk, especially in the discussions as to whether raw or boiled milk is the more digestible for infants and in connection with the diseases of metabolism, such as scorbutus and rachitis.

The study of the ferments is open to error because of the presence of bacteria in milk. It is almost impossible to obtain a truly sterile milk and to keep that milk sterile for any length of time. The use of toluol or chloroform to keep the milk sterile may modify or destroy the enzymes, while sterilization by heat destroys the enzymes. Since the action of bacteria may cause all the phenomena produced by the ferments in milk, the action of bacteria must always be excluded.

[1] Moro: München. med. Wchnschr., 1912, lix, 2553.
[2] Bauer: Monatschr. f. Kinderh., 1912-13, orig. xi, 474.
[3] Tugendreich: Berl. klin. Wchnschr., 1911, xlviii, No. 1, p. 224.

The Proteolytic Ferments.—(a) Casease has the property of converting casein into soluble albumin.[1] It is found in human and cow's milk.

(b) Pepsin and Trypsin: Both of these ferments are supposed to be present in cow's and human milk (Spolverini [2]), the one acting in acid media and the other in alkaline surroundings. Other investigators [3] could not convince themselves that there were any such ferments in demonstrable quantities. The proteolytic ferments, according to Freeman [4] are not affected by heating for one-half hour at 65 C. (149 F.) or for one hour at 60 C. (140 F.). They are destroyed by boiling.

(c) Fibrinogen: Schlossmann [5] observed that human milk caused the coagulation of the hydrocele fluid from a young infant, while cow's milk did not. This observation was subsequently confirmed.[6] It was shown that this ferment is not destroyed by heat [7] and that it is sometimes found in cow's milk.[8]

Carbohydrate-Splitting Ferments.—Amylase [9] has the power of splitting starch into dextrin and of continuing the process until a very little of it is converted into maltose.[10] This ferment is present in human milk. According to some investigators it is not present in cow's milk. Others[11] using different methods, always find it in cow's milk. The action of amylase is increased by the addition of peroxid of hydrogen.[12] It is destroyed at the temperature of 75 C. (167 F.), perhaps at a somewhat lower one. It appears to pass into the whey when the casein is precipitated.

A disaccharid-splitting ferment has been reported in cow's milk which is capable of splitting lactose; it may also be present in human milk.[13] It is not changed by heating for one-half an hour at 65 C. (149 F.) or for one hour at 60 C. (140 F.), but is weakened

[1] Raudnitz: Ergebn. d. Physiol., 1903, ii.

[2] Spolverini: Arch. de méd. d. Enf., 1901, iv, 705.

[3] Moro: Jahrb. f. Kinderh., 1902, N. F., lvi, 391; Hippius: Jahrb. f. Kinderh., 1905, lxi, 365.

[4] Freeman: Jour. Am. Med. Assn., 1907, xlix, 1740.

[5] Schlossmann: Verhandl. d. xviii Versamml. Gesellsch. f. Kinderh., Hamburg, 1901.

[6] Moro: Wien. klin. Wchnschr., 1902, xv, 121.

[7] Moro and Hamburger: Wien. klin. Wchnschr., 1902, xv, 121.

[8] Bernheim-Karrer: Zentralbl. f. Bakt., 1902, xxxi, 388.

[9] Disatase, zymase, diastatic ferment.

[10] Bechamp: Compt. rend., Acad. d. sc., 1883, 96.

[11] König: Milchwirtschol: Zentralbl., 1907, iii.

[12] Lagane: Compt. rend., Acad. d. sc., 156, 1941.

[13] Stoklasa: Arch. f. Hyg., 1904, l, 165.

by heating for a short time at 70 C. (158 F.) and is destroyed at 75 C. (167 F.).[1]

Fat-Splitting Ferment.—This ferment decomposes neutral fats into fatty acids and glycerin.[2] It is found in both human and cow's milk. This ferment in human milk breaks tributyrin into butyric acid in a very few minutes, but in cow's milk only after many hours. This test may be used to differentiate raw human milk from boiled human milk, and raw and boiled cow's milk.[3] The ferment is, therefore, present in relatively large amounts in human milk, but only in traces in cow's milk. Heating to 60 C. (140 F.) does not affect it, while 64 C. (147.2 F.) destroys it.

Salol-Splitting Ferment.—It was found that human milk had the power of splitting salol. This power was not destroyed by heating to 100 C. (212 F.). Further investigation showed that this phenomenon was not due to a ferment, but was purely chemical. Salol is split in an alkaline medium of the same alkalinity as human milk. When cow's milk is brought to the same grade of alkalinity it also will split salol.[4]

Oxydase and Reductase.—(a) *Superoxidase:* Superoxidase is the name given to the ferment which reduces peroxid of hydrogen into water and oxygen. It acts best at about 37 C. (98.6 F.) and is destroyed at about 68 C. (154.4 F.). During centrifugalization it rises with the cream.[5] There is a large amount both in human milk and cow's milk.

(b) *Peroxidases:* Peroxidases hasten the oxidation of such bodies as tincture of guaiac. They pass into the cream during centrifugalization and in fractional precipitation are precipitated along with the globulins.[6] There is no definite temperature at which this enzyme is destroyed, because the rate of heating modifies the results.[7]

(c) *Reductase:* When reductase comes in contact with sulphur and water it converts the sulphurin to the corresponding hydrids;[8]

[1] Freeman: Jour. Am. Med. Assn., 1907, xliv, 1740.

[2] Marfan and Gillet: Monatschr. f. Kinderh., 1902–3, 1, 57; Moro (*loc. cit.* note 3); Hippius (*loc. cit.*, page 117).

[3] Davidsohn: Ztschr. f. Kinderh., 1913, viii, 14.

[4] Demoulieres: Jour. de pharm. et chim., 1903, xvii; Miele and Willen: Compt. rend., Acad. d. sc., 1903, cxxxvii.

[5] Hecht and Friedjung: Arch. f. Kinderh., 1903, xxxvii, 177.

[6] Raundnitz: Pfaundler and Schlossmann: Diseases of Children, Philadelphia and London, 1908, i, 308.

[7] Van Eck: Chem. Weekblad, viii, 692, ref. Chem. Abstr., Jan. 10, 1912.

[8] Rey: Pailhade quoted from Possi-Escot: Etat actuel sur les oxydases et reductases, Paris, 1902.

it also reduces methylene blue [1] and decolorizes Schardinger's reagent.[2] It is stronger in cream than in skimmed milk [2] and is precipitated with the casein. It is found in both human and cow's milk. Its action with Schardinger's reagent [3] is used in differentiating raw from boiled milk. Heating milk to between 70 C. (158 F.) and 80 C. (176 F.) stops the reaction. Reductase is most active between 40 C. (104 F.) and 55 C. (131 F.).

TRANSMISSION OF TOXIC BODIES AND IMMUNITY THROUGH MILK

Toxins.—Sonnenberger [4] concluded from his investigations that milk is not only a secretion but an excretion and that, therefore, many vegetable poisons in the food of animals may go over in the milk. Among these poisons are alkaloids, glycosids and amids, as well as volatile and ethereal oils, and dibasic organic acids.

Toxins may be formed as the result of the metabolism of certain bacteria, may be produced by plants, or may come from the secretions or body components of certain animals.

Antibodies.—Ehrlich [5] was the first to show that immunity could be transmitted to the infant through the milk. The fact that breast-fed infants seem to be less liable to such diseases as measles, scarlet fever, mumps and typhoid fever is used by many as an argument that immunity is transmitted through the breast-milk.

Antitoxin.—It has been shown that in animals immunity to the bacillus of anthrax and the pneumococcus is transmitted by the mother to the young. It is impossible to say, however, whether this immunity is transmitted through the milk or is acquired during intrauterine life.[6] Ehrlich [5] concluded from his researches that artificial immunity can only come through the milk of the mother. When a mouse which was born of a normal mother, which was not immunized, was fed by a mouse immunized with antitoxin, the suckling developed immunity. The amount of antitoxin that

[1] Pozzi-Escot (see note 8, page 118).

[2] Smidt: Hyg. Rundschau, 1904, xiv, 1137; Hecht: Arch. f. Kinderh., 1904, xxxviii, 349.

[3] Five c. c. saturated alcohol solution of methylene blue, 5 c. c. formalin, 190 c. c. water.

[4] Sonnenberger: Therap. Monatschr., 1901, xv, 6; Sonnenberger: lxxi Naturforschersamml., München, 1899.

[5] Ehrlich: Ztschr. f. Hyg. u. Infectionskr., 1892, xii, 183.

[6] Chauveau: Ann. de l'Inst. Pasteur, 1888, ii, 66; Klemperer: Arch. f. Exper. Pathol. u. Pharm., 1892–93, xxxi, 356.

passes from the mother through the milk to the suckling is between one-fifteenth and one-thirtieth of the total amount in the mother, depending on the amount of lactalbumin and globulin that her milk contains.[1] It was impossible to immunize the human infant by feeding it with horse antitoxin, but when its own mother or the wet-nurse was immunized with horse antitoxin the immunity was transferred through the milk to the nursing infant even as early as the fourth week of life.[2] Immunity can, therefore, be transferred by way of the milk or albumins of the same species, but not by those of another species.

Agglutinins.—The same question comes up in studying the agglutinins as in the case of the antitoxins as to whether the property of agglutination is acquired during intrauterine life or passes through the milk.

The evidence that it may be transferred by the mother through her milk to the infant is in part positive and in part negative. Romer,[3] after summing up the literature, concludes that agglutinins may be transferred in the milk. The agglutinins in the milk of the mother are more easily absorbed from the infant's gastrointestinal canal than those in the milk of animals.

Bactericidal Substances.—The fact that the blood of infants that are nursed at the breast contains stronger bactericidal substances than that of those fed on the bottle [4] is evidence in favor of these substances being carried in the milk, in spite of the fact that they cannot be demonstrated in the milk itself.

Hemolysin.—Hemolysin has recently been demonstrated as a normal constituent of the different kinds of milk.[5] It is absent from colostrum in the majority of cases tested on the second day postpartum.[6] *Hemagglutinins* are found in human milk that react differently toward the blood corpuscles of different species of animals.[7]

Opsonin.—The milk is poorer in opsonins than the blood serum

[1] Brieger and Ehrlich: Ztschr. f. Hyg., 1893, xiii, 336; Brieger and Cohn: Ztschr. f. Hyg., 1893, xv, 1; Wassermann: Ztschr. f. Hyg., xviii; Ehrlich and Wassermann: Ztschr. f. Hyg., 1894, xviii, 235; Romer: Berl. klin. Wochenschr., 1901, xlvi, 209; Kayser: Ztschr. f. klin. Med., 1905, lvi, 17.

[2] Salge: Jahrb. f. Kinderh., 1904, lx, 1.

[3] Romer: Sommerfeld's Handbuch der Milchkunde, Wiesbaden, 1909, 492.

[4] Moro: Jahrb. f. Kinderh., 1902, lv, 396.

[5] Pfaundler and Moro: Ztschr. f. Exper. Pathol. u. Therap., 1907, iv, 451.

[6] Kolff and Noeggerath: Jahrb. f. Kinderh., 1909, lxx, 701.

[7] Zubczycki and Wolfsgruber: Deutsch. med. Wochenschr., 1913, xxxix, 210.

of the mother [1] while the colostrum contains more than the milk.[2]

Hypersensibility.—Hypersensibility (sensitization) toward various poisons and albumins may pass over in the milk to the infant and be absorbed.[3]

[1] Turton and Appleton: Reference, Deutsch. med. Wochenschr., 1907, xxxiv.
[2] Tunnicliff: Jour. Infect. Dis., 1912, xi, 347.
[3] Otto: München. med. Wochenschr., 1907, liv, 1665.

CHAPTER XI

CLINICAL CONSIDERATIONS AND TECHNIQUE

The contraindications to nursing have already been mentioned, and the ability of women in general to nurse their babies has already been referred to. Far more women are able to nurse their babies than is generally supposed. As a matter of fact, very few women are entirely unable to nurse. The so-called inability to nurse is in many instances unwillingness rather than inability. Many women are, however, thought to be unable to nurse when they really are able. The attempt at nursing is not infrequently given up too soon because the milk is late in appearing. The production of milk begins in two ways: either the quantity of milk slowly, but gradually, increases or, after a very small secretion in the beginning, there is a very sudden increase, which is often spoken of as the "running-in" of the milk. The supply of milk is often considered insufficient when the "running-in" is delayed, and breast feeding is therefore considered impossible. Dluski's figures [1] show how different the time of the "running-in" of the milk may be. She found that in 326 primiparæ the running-in of the milk occurred as follows: 9 times after 24 to 48 hours, 115 times after 48 to 72 hours, 159 times after 72 to 96 hours, 42 times after 96 to 120 hours, one time after 120 to 144 hours. The best method of hastening the appearance of the milk is by emptying the breasts as completely as possible. The best way to do this is by putting an older and stronger infant to the breast. The older infant not only sucks more strongly, but does not get as tired as the younger child, who often refuses to nurse after a few attempts, if the milk does not flow easily. If an older baby cannot be obtained, the mother's own infant may be used.

The supply of milk is not infrequently insufficient while the mother is in bed, and nursing is on this account given up. It is not uncommon, however, to have the supply of milk increase and be amply sufficient after the mother is able to be out of bed and to take up her ordinary routine.

It is sometimes thought that it is not worth while for a woman to nurse her baby unless she can nurse it for a considerable time.

[1] Thèse de Paris, 1894.

This belief is, of course, entirely erroneous, because there is no time in a baby's life at which it is more important for it to have breast-milk than in the beginning. There is no time at which a baby's digestion is so easily disturbed and so hard to correct, if disturbed, as in the early days and weeks of life. Every day or week that a baby gets breast-milk gives it a better start and makes it easier to put it on an artificial food later, if it is necessary. It is also sometimes thought that it is hardly worth while to give a baby the breast, unless it can get all its food from the breast. Others believe that it is dangerous to mix human milk and artificial food. This belief is, of course, entirely erroneous. The artificial food cannot make the breast-milk harder of digestion, while the breast-milk clinically certainly seems to make the digestion of the artificial food easier. Every little bit of breast-milk helps the baby and makes it easier to feed it artificially. This may be due in part to the ferments which the breast-milk contains, but more probably is due to the fact that the baby is able to utilize the proteins of human milk to build tissues, when it is not able to utilize the proteins of the artificial food in the same way.

Nursing is sometimes given up almost at once because of poor nipples or cracked nipples. Nursing should not be given up for these reasons until strenuous attempts have been made to draw out the nipples or to have the baby nurse with a nipple-shield. Cracked nipples will almost invariably heal if time and trouble enough are taken.

In other cases nursing is not attempted because it is feared that the strain of nursing will be too great for the health of the mother. It is true that in some instances nursing does pull down the mother materially. It must not be forgotten, however, that nursing is a physiological and not a pathological condition, and that many women are better while nursing than at any other time. Even if it does pull a woman down, however, a mother should be willing to sacrifice herself to a certain extent in order to give the baby a good start. A few weeks or a few months of nursing will make all the difference to the baby in the future. It is often said that women are too nervous to nurse, that their milk will be bad on this account and that the baby will be disturbed and will not thrive. This is undoubtedly true in a certain number of instances. Other women, however, apparently as unsuitable for nursing, prove to be very good nurses. On this account, therefore, nursing should always be attempted, to be given up later if it is not successful.

In general, women are altogether too prone to believe on insufficient grounds that they cannot nurse their babies. It is sad to

say that they are often aided and abetted in this belief by physicians and nurses, who should know better. It is a hopeful fact, however, that the women among the well-to-do and educated classes are beginning to appreciate the importance of breast feeding and that many more of them are not only willing but anxious to nurse than were a few years ago.

Feeding in the First Few Days of Life.—The baby should be put to the breast from six to twelve hours after birth, according to the condition of the mother and the strength of the baby. The object of putting the baby to the breast at this time is not to give the baby food, but to stimulate the breast to secretion. It is supposed that nursing also favors the involution of the uterus. There is, however, no positive proof that this is so. The baby should be put to the breast every six hours during the next twenty-four hours, and every four hours during the succeeding twenty-four hours. With the appearance of the milk, the interval may then be shortened. The average amount of colostrum obtained during the first twenty-four hours is from 4 to 6 c. c., and during the second twenty-four hours, 90 c. c. In the majority of cases the milk then comes in rapidly on the third and fourth days. In many instances, however, the milk does not come in until a day or two later than this. It is evident from the small amount of colostrum secreted during the first two or three days that the baby is not intended by nature to get much food during this time. Further proof of this fact is that the initial loss of weight is not prevented by feeding larger amounts of food from the beginning. It is well, however, to give the baby water freely in order to flush out the kidneys and make up for the water lost in other ways. One or two drachms should be given every two hours, more often if the baby wishes it and will take it. It is often advisable to give a solution of milk sugar and water at this time in order to favor the development of the normal bacterial flora. There is no proof, however, as to whether this is accomplished or not. Some believe that sugar at this time does harm, but there is no proof whether it does or not. It is probably, however, better on the whole to give a mixture of saccharin and water than sugar and water.

Most babies begin to show signs of hunger after the first forty-eight hours. It must be remembered, however, that crying at this time does not necessarily mean hunger, because every new-born baby cries a certain amount. It is wiser to begin to give some food on the third day, if the supply of breast-milk is insufficient. It is not necessary to begin to feed them at this time, however, as experience has shown conclusively that it does the baby no harm

to go four or five days without food. It is very important, when beginning to feed a new-born baby, not to give it too much food or too strong a food. There is no time in a baby's life in which it is so easy to disturb the digestion or at which it is so difficult to correct the disturbance, if it is once caused. If the baby is put to a breast whose secretion is already established, there is great danger that it will take too much food and be disturbed by it. The duration of nursing must, therefore, be very short in the beginning. It is often wiser to give breast-milk diluted with water from a bottle for one or two days before putting the baby to the breast. It is probable, too, that the baby digests breast-milk better if it has had colostrum first. There is, however, no proof of this.

If the baby has to be given an artificial food, it is very important not to give it too strong a mixture. It is absolutely wrong to say, as many physicians do, "Give it a little milk and water. It is not necessary to give it a mixture at this time, because it will be on the breast in a few days." The digestion is so easily disturbed at this time that there is no time at which it is more important to give a mixture suited to the baby. It is very important to begin with a weak mixture and to give it in small amounts. If this mixture is digested and the baby is still hungry, it is very easy to increase the strength and the amount of the food. If the baby is upset by too strong a food, it is a very difficult matter to correct the disturbance. The mixture should be low in fat and proteins, which are relatively hard to digest, and proportionally high in sugar, which is easy of digestion at this time. It is wise, also, to give a part of the proteins in the form of the whey proteins. A suitable mixture is fat 1%, milk sugar 5%, whey proteins 0.25%, casein 0.25%. This may be quickly strengthened, perhaps in the first twenty-four hours to fat 1.50%, sugar 6%, whey proteins 0.50%, casein 0.25%, and then in another twenty-four hours to fat 2%, sugar 6%, whey proteins 0.75% and casein 0.25%. Two drachms (10 c. c.) is enough at first. This can be quickly increased to one-half to one ounce (15 or 30 c. c.).

The colostrum is supposed to have a laxative action. Such an action, however, has not been proven. If the bowels have not moved well during birth or during the first twenty-four hours, it is wise to give a teaspoonful of castor oil in order to empty them, because of the possible danger of the absorption of the products of decomposition of retained meconium. It is probable that these products may cause convulsions and other severe nervous symptoms, as well as fever and marked prostration. At any rate, such

symptoms in the new-born are repeatedly relieved by the emptying of the intestinal tract.[1]

Intervals between Nursings.—There is much difference of opinion as to the proper intervals between nursings. This subject will be discussed later in detail in the chapter on artificial feeding.

Regularity of Nursing.—Whatever intervals between nursings are adopted, the baby should be nursed regularly at these intervals. There is, of course, no doubt that many babies thrive in spite of being nursed at any and all times. On the average, however, babies do better when they are fed regularly. A baby quickly accommodates itself to being fed at regular intervals and soon learns to expect to be fed at these times and not at others. The mother, moreover, can arrange her time much better, if she knows when the baby is to be fed. It is very difficult for the modern woman, who has many other legitimate demands upon her time, to always be on hand at the nursing time. One bottle feeding a day makes it much easier for many women and enables them to nurse their babies when they would otherwise not be able to do so. An additional advantage in one bottle feeding a day is that the baby becomes accustomed to the bottle and weaning is, therefore, much easier when it becomes necessary. It is especially pernicious to nurse the baby off and on all night. If this is done, the sleep of both mother and baby is disturbed and they suffer, the mother the more, from the loss of sleep. A baby should not be nursed more than once in the night, and this nursing should be stopped when the baby is a few weeks old.

Waking to Nurse.—It is claimed by some authorities that a baby should not be waked to nurse, but should be allowed to sleep as long as it desires and nurse when it awakens, the only rule as to the length of the interval between nursings being that it shall not be less than 2 hours, so as to avoid feeding before the stomach is empty. There is no doubt that babies will thrive on this system of breast feeding, as they will on almost any scheme of breast feeding. This method is, however, not suited to the exigencies of modern life. Most women have to arrange their time systematically in order to fill all their engagements and cannot wait, therefore, on the baby's convenience. It is much wiser, on the whole, to wake the baby at the proper time. A normal baby that is fed regularly wakes in most instances at regular intervals and, in any case, will quickly go to sleep again after being nursed.

Alternate Breasts.—If the supply of milk is sufficient, it is usually advisable to give the breasts alternately. By this method

[1] Morse: Amer. Journal of Diseases of Children, 1912, iv, 229.

the breasts are more thoroughly emptied and the production of milk is encouraged. If both are given at the same time, they are not emptied and the production of milk is discouraged. There is, moreover, a tendency to reversion to the colostrum stage. If the supply of milk is insufficient, it is advisable to give both breasts at each feeding. The baby in this way gets a sufficient amount of food, the breasts are emptied and the production of milk is encouraged.

Duration of Single Nursing.—If the supply of milk is abundant and the baby well and vigorous, it will usually occupy about twenty minutes in nursing. Many normal babies will, however, take only ten or fifteen minutes in nursing. The time taken in nursing varies according to the sucking strength of the baby, the amount of milk in the breasts, and whether the breast is one which it is hard or easy to empty. It must be remembered in this connection that the milk flows most freely at the beginning of a nursing, and that the amount obtained diminishes progressively with the duration of the nursing. The baby gets more than one-half of the meal in the first five minutes, more than one-quarter in the next five minutes, and but comparatively little after this. [1] If the baby nurses more than thirty minutes there is something wrong. The trouble may be that the supply of milk is insufficient, or that the baby is too feeble to nurse vigorously and continuously. The baby should not drop off to sleep while nursing. If it does, it means that the supply is insufficient and he gives up after getting a little, that he is not hungry and that the intervals should therefore be lengthened, or that he is feeble or sick in some way. While the supply of milk is greatest at the beginning of the nursing, the strength of the milk increases progressively throughout the nursing, the total solids being greater at the end than at the beginning of a nursing. This difference is, however, not great enough to be of much practical importance.

Amount Taken at Each Nursing—The amount taken at a nursing varies materially from nursing to nursing and bears no relation to the theoretical size of the stomach. A baby will take two ounces at one feeding, and six ounces at the next, and so on. A baby three weeks old will sometimes take as much as six ounces at a nursing, and one of two months as much as eight ounces at a nursing, and so on. The amount taken in twenty-four hours will, however, be approximately the same from day to day, increasing, of course, with the age of the baby.[2] Variations in the amount of

[1] Feer: Jahrbuch f. Kinderheilkunde, 1896, xlii, 195.
[2] Peters: Archiv. f. Kinderheilkunde, 1902, xxxiii, 295.

fat in the milk do, however, influence the total amount taken in twenty-four hours, less being taken when the percentage of fat is high. The explanation of the difference in the amount taken at different feedings is probably either that there is a variation in the supply of milk or that the baby is not as hungry at one time as at another. If it has taken a large amount at one feeding, it will naturally not take as much at the next and vice versa. The explanation of the fact that a baby can take an amount at a single nursing far in excess of its gastric capacity is that the milk passes directly into the duodenum, even during the act of nursing.

Difficulty in Technique of Nursing.—If a baby does not nurse well, the trouble may be with the baby or with the mother. If the trouble is with the baby, it may be some deformity of the lips or mouth, nasal obstruction from adenoids or some other cause, which interferes with nursing, or weakness. Older babies that have been fed on the bottle are often unwilling to take the breast, because they are unaccustomed to it. Babies that are partly bottle and partly breast-fed will often refuse the breast because they have to work harder to get the milk from the breast than they do to get it from the bottle.

Retracted or small nipples are the most common cause of difficulty in nursing on the part of the mother. In rare instances the nipples are too large. Cracked nipples also frequently interfere with satisfactory nursing. Many mothers do not know how to hold a baby to make it comfortable while nursing. Other mothers, through nervousness, disturb the baby and prevent it from taking hold and nursing satisfactorily.

Treatment.—Deformities of the mouth and lips must be corrected. In general, it is not wise to operate on a hare-lip until the baby is at least six weeks old, or on a cleft-palate until it is at least six months old. The baby can be fed with breast-milk by means of a dropper, spoon, Breck feeder or tube in the meantime. Adenoids should be removed at once if they cause interference with nursing, no matter how young the baby may be. Feeble babies can be fed wholly or in part in the same ways as those with deformities of the mouth and lips. Babies that are unwilling to take the breast can usually be starved to it. Putting sugar on the nipples, pressing some of the milk into their mouths at the beginning of nursing, or the use of a nipple-shield will sometimes induce them to take hold. They will sometimes nurse in the dark or when blindfolded, when they will not otherwise.

Care of the Nipples.—Something can be done during pregnancy to bring out retracted nipples by manipulation, careful application

of a breast-pump and sucking. The nipples should be carefully washed and cleaned during the latter days of pregnancy in order to remove the excess of epithelium and to clear the openings of the ducts.

The nipples should be washed before and after each nursing with sterile water or with a saturated solution of boracic acid and thoroughly, but carefully, dried with a soft cloth or absorbent cotton. It is wise to protect them with a cloth moistened with albolene or boracic acid ointment between the nursings. If the nipples are tender they may be washed with a 50% solution of alcohol. If the nipples become cracked, the baby should not be allowed to nurse, except through a nipple-shield. If it does not thoroughly empty the breasts in this way, they should be emptied by massage or a breast-pump. Cleanliness and a simple ointment, like boracic acid ointment, are usually sufficient to heal them. In some instances, however, it is necessary to touch the cracks with a 1% or 2% solution of nitrate of silver. If the breasts are full or tender, they should be supported with a breast-binder and kept empty by massage and a breast-pump. It is safer, as a rule, to take the baby off of an inflamed breast and empty the breast by massage or with a breast-pump. If the milk contains no pus corpuscles there is probably, however, no risk to the baby, if the nursing is continued.

Breast-Pumps and Nipple-Shields.—The so-called English breast-pump is the most satisfactory. The glass nipple-shields with a rubber nipple are the best. A baby will often nurse better from a shield if it is first filled with milk.

Care of Baby's Mouth.—There is always danger of infection of the nipples and breast from the baby's mouth, if it is not kept clean. The condition of the baby's mouth must, therefore, be watched. It is far more likely to become inflamed and infected, if it is washed than if it is left alone. The baby's mouth should, therefore, not be washed. A swallow of water after nursing is all that is necessary.

Method of Nursing Baby.—The baby should be held lying on its side with its head a little elevated. It must be everywhere supported, so that it is relaxed and comfortable. The breast above the nipple must be pressed away from its nose, so that it can breathe freely. The mother and attendants must be quiet and composed. Otherwise the baby is disturbed and excited and will not nurse well.

Not all Human Milk is Good Milk.—Everyone agrees that human milk is the best food for infants. It is equally true, however,

that not all human milk is good milk. Some milks will not agree with any baby. Other milks will agree with one baby and not with another. A milk which suits one baby will not suit another, and what suits the second baby will not suit the first baby. It is impossible to determine from an analysis of a milk whether it will or will not agree with a given baby. This can only be told by experience. Babies will often thrive on a milk which would, from its analysis, seem most unsuitable. The same baby will often thrive on different types of milk. While it is impossible to determine from an analysis of the milk whether it will or will not agree with a baby, it is, however, often possible, if a milk is not agreeing with a baby, to tell from the analysis why it does not. If a milk does not agree with a baby, the most common abnormality in the milk is an excessive amount of proteins. The next most common abnormality is an excess of fat. There is very seldom an excess of sugar.

Types of Abnormal Milk.—Human milk may be unsuitable or abnormal in many ways. Three general types can be recognized.

(1) All elements too high.
(2) Fat and sugar low, proteins high.
(3) Fat and sugar very low, proteins very high.

The first type is most often found in indolent women of the wealthy classes, who, being blessed with a good digestion, eat too much and too rich food. An example of such a milk is the following

Fat	5.00%
Sugar	7.50%
Proteins	2.60%

There is no difficulty in correcting this type of milk, provided the woman will eat properly and take exercise. It is, however, unfortunately rather hard to induce such women to change their habits.

The second type is most often found in women of the poorer classes who are compelled to work hard and do not have sufficient food. It is, in fact, a starvation milk. A typical analysis of such a milk is

Fat	1.75%
Sugar	4.50%
Proteins	2.50%

This type of milk is also easily changed by giving sufficient food and diminishing the work. Unfortunately, it is, in this instance also, difficult to remedy the underlying social conditions.

The third type is usually found in the highly-strung, over-educated and highly-civilized women of the large cities, but may be found in neurotic women of any class or community. A characteristic analysis of this type of milk is

Fat	1.00%
Sugar	4.00%
Proteins	3.75%

It is practically impossible to modify this type of milk, because it is impossible to change the fundamental abnormality of the woman's nervous make-up.

Analysis of Breast-Milk.—Too much reliance must not be placed on an analysis of the breast-milk, because the composition of milk varies in the same woman from day to day and from nursing to nursing. It also differs at different periods of the same nursing. An analysis is valueless, therefore, unless all the milk is taken from the breast, or at least samples from the beginning, the middle and the end of the nursing. The results of a single examination, even if the milk is properly taken, may also be misleading, because of the variation from day to day and nursing to nursing. Positive conclusions can be drawn only when the results of several examinations are similar.

The Normal Breast-Fed Infant.—A baby that is thriving on the breast should gain from six to eight ounces a week during the first five months, and from four to six ounces a week during the rest of the first year. Smaller but steady gains are, however, not necessarily abnormal. It should double its birth weight in the first five months, and treble it at the end of the first year, or a little later. It should have from two to four smooth, orange-yellow stools of the consistency of thick pea-soup daily during the first few months, and from one to three similar stools of somewhat greater consistency during the rest of the first year. It should not vomit unless it is disturbed or shaken up soon after a feeding. It should not cry unless hungry or when uncomfortable from wet diapers, wrinkles in its clothing, and so on. Its flesh should be hard and firm, its lips, cheeks and nails pink. It should sleep from twenty to twenty-two hours out of the twenty-four during the first two months, and about sixteen hours a day during the latter half of the year. It should be happy when awake, active when given the opportunity.

Theoretically the normal baby should gain regularly every day and should never lose. Practically this never happens. The baby gains one day, remains stationary another day and loses on a third,

there being, however, a steady gain from week to week. Very few babies, however, get through the year without, for some reason, which may or may not be apparent, failing to gain or lose for one or more weeks.

Many babies that are gaining regularly and apparently thriving in every way on the breast have abnormal stools. The attempt should be made to correct these stools by modification of the milk through regulation of the mother's diet and life. The baby should not be taken off the breast, however, even if the attempt is unsuccessful. A baby that is gaining and thriving in other ways should never be weaned simply because the stools are abnormal, no matter how abnormal they may be. Many a baby has been injured, and not a few killed, by being taken off the breast on this account. It must never be forgotten that stools which in the artificially-fed baby mean serious disturbance of the digestion and demand prompt modification of the food can be practically disregarded in the breast-fed, provided the babies are thriving in other respects.

The Abnormal Breast-Fed Infant.—When a breast-fed baby, which is not gaining properly, has one or more normal stools daily it is almost certain that the failure to gain is not due to any defect in the quantity or quality of the milk. The source of the trouble must be sought elsewhere. It will then be found that the baby is being improperly handled in some way or that it has some disease. It may be that it is excited too much, that it does not get enough sleep, that it does not get enough fresh air, or that it is not kept warm enough. Hidden tuberculosis, pyelitis and an insufficient supply of air as the result of adenoids are frequent causes of failure to gain.

Failure to gain in weight may or may not be associated with symptoms of disturbance of the digestion.

If there are no symptoms of disturbance of the digestion and the baby is constipated, as it usually is, the food is deficient in quantity, quality, or both. If the supply of food is sufficient to supply the pangs of hunger, the baby will not appear hungry, even if the food is entirely inadequate to enable it to gain in weight.

The only way to determine how much milk a baby is getting from the breast is to weigh it before and after each nursing for twenty-four hours. The difference in weight shows the amount of milk taken, as an ounce of milk weighs practically one ounce avoirdupois. It is not sufficient to weigh the baby before and after one or two nursings, because of the difference in the amount of milk taken at different nursings. The total amount taken in

twenty-four hours must always be determined. It is, of course, unnecessary to undress the baby in order to weigh it. If the baby is restless and it is hard to weigh it accurately, the same result can be obtained by weighing the mother before and after nursing. What she loses represents, of course, the amount of milk taken by the baby.

Other methods of estimating the amount of milk are very unreliable. It is impossible to tell the amount of milk from the size of the breasts. Many large breasts secrete but little milk, while other small breasts secrete a considerable amount of milk. It is impossible, also, to determine the amount of milk by attempting to express it or by taking it out with a breast-pump, because a baby will often get a large amount of milk from the breast when but little or nothing can be obtained by expression or with a pump. Evidence of considerable importance in favor of an insufficient supply of milk is when a baby wakes up hungry some time before every feeding. Other suggestive evidence is when a baby drops the nipple during the feeding and cries with anger, or when it grabs the nipple and shakes it as a puppy does a root.

The quality of the milk can only be determined by chemical analysis. Great care must be exercised, however, in the interpretation of the findings of such an analysis, as has already been explained. Under these conditions the milk is usually weak in all its constituents, or the percentage of fat is very low, while the other elements are approximately normal.

When there are symptoms of a disturbance of the digestion, there is either an excessive amount of milk or the quality of the milk is abnormal. When there is an excessive amount of milk the baby usually vomits, especially soon after nursing, and has too many stools, which, in most instances, are in some way abnormal. The quantity of the milk can only be positively determined, however, by weighing the baby or the mother before and after each nursing for at least twenty-four hours. Abnormalities in the composition of the milk are shown by colic, vomiting and abnormal stools. The abnormality is usually an excess of fat or proteins, more often of proteins, rarely of sugar. An excess of fat is shown in most instances by the presence of small, soft curds in the stools, the typical soap stool being unusual in the breast-fed baby. When there is an excess of proteins, the stools are likely to be watery, to be somewhat brownish in color and to contain mucus. They are often greenish and frequently contain mucus when the milk is abnormal in any way, but the typical, green, fermented, irritating stool of an excessive amount of sugar is seldom seen. The only way in which

the error in the composition of the milk can be accurately determined, however, is by chemical analysis of the milk, due regard being paid to the possibilities of mistakes in drawing conclusions from such analyses.

Modification of Breast-Milk.—The secretion of breast-milk and the various factors which influence it have been discussed in a previous chapter. It will perhaps be well, nevertheless, to review the subject from the clinical standpoint. In the first place, lactation is, or should be, a physiological, not a pathological process. A nursing woman is in a normal, not an abnormal, condition. She should, therefore, lead the same sort of life when she is nursing that she does when she is not nursing, provided her manner of living is a normal one. In view of the fact that there is a certain amount of additional strain in nursing, she should be careful not to overdo or to get overfatigued. Her diet should be that to which she is accustomed when she is not nursing. There is no reason why she should not eat anything which does not disturb her digestion, but should, as when not nursing, avoid articles of food which disagree with her. There is very little in the old theory that a nursing woman should avoid certain fruits and vegetables because they will disturb the baby's digestion. It is true that sometimes when a given woman eats a given thing the baby will be disturbed. It is impossible to tell in advance, however, what this thing will be. Moreover, the thing which causes disturbance in one instance will not cause disturbance in the next, while something else will. A nursing woman should, therefore, eat a general diet, avoiding articles of food which disturb her digestion. If her baby is upset, she should try to remember what unusual article of food she has eaten. If the baby is upset when she eats it again, she should avoid it in the future.

Modification of Quantity of Breast-Milk.—In the first place, it must be remembered that Nature tends to accommodate the supply of breast-milk to the demand. If but little is taken, little will be produced. If much is taken, much will be produced. The best stimulant to the secretion of milk is the thorough emptying of the breast. There is nothing else which tends to increase the quantity so much. The next best stimulants to the secretion of milk are a liberal, general diet and a normal life. Increasing the quantity of liquid in the diet increases the quantity of milk to a certain extent. It is useless, however, for a woman to take more than a quart of extra liquid daily. More than this either disturbs her digestion or makes her grow fat. This extra liquid should not be too rich. It is given chiefly for its action as a liquid, not as a

food. If it is given in the form of chocolate, eggnogs, and things of like nature, it takes away the appetite for solid food, and the total ingestion of food is not only not increased but often diminished. Milk and cocoa shells are probably the best drinks. Gruels seem to have a certain action as galactagogues. So do malt liquors in some instances. It is better not to use them as a rule, however, because they are likely to disturb the digestion and fatten the mother. There is no danger to the baby from their alcoholic content. There are no drugs which, whether taken internally or applied externally, can increase the flow of milk to any appreciable extent.

It is seldom necessary to diminish the quantity of milk. Diminution in the amount of food and liquid ingested will usually speedily diminish the supply of milk. Moreover, if the breasts are not thoroughly emptied, Nature will quickly reduce the supply. External applications are usually not efficacious and always inadvisable. The bowels may be opened freely, if necessary, to reduce the amount of milk temporarily.

Modification of Quality of Breast-Milk.—When the total solids of the milk are all high, as the result of overeating and lack of exercise, they can be reduced by regulation of the diet and exercise. When they are low, as the result of starvation and malnutrition, they can be increased by proper food and care. They can also be influenced to a certain extent by varying the intervals between nursings. Lengthening the intervals diminishes the total solids; shortening the intervals increases them.

It has been taught for many years that the amount of fat in the milk varies directly with the amount of protein in the food. This teaching is, however, erroneous, the only way in which the protein in the food can increase the fat in the milk being by improving the general condition. The amount of fat in the food has but little influence on the amount of fat in the milk. If the mother is underfed, an increase in the fat in the food will temporarily result in an increase in the fat in the milk. If she is not underfed, an increase in the fat in the food does not increase the fat in the milk. An excessive amount of fat in the milk is most often due to an excessive amount of food in general rather than to an excess of any one element and can be diminished best by cutting down the food as a whole. An insufficient amount of fat in the milk is usually due to malnutrition. It can be increased by building up the general condition by increasing the supply of food and regulation of the life. An increase in the amount of fat in the food will also sometimes temporarily cause an increase in the percentage of fat in the

milk. When a breast-milk is low in fat, but otherwise of good quality, it is easy to make up for the deficiency of fat by giving the baby cream with the nursings. Enough cream should be given to bring the percentage of fat to the proper level. For example, if a baby is taking four ounces of breast-milk, containing 1% of fat, the addition of one-half ounce of gravity cream will raise the percentage of fat to three. The cream may be given before or after the nursing, but is best given in the middle of the nursing. A very good way to give it is from a dropper introduced into the mouth beside the nipple while the baby is nursing.

The percentage of the sugar in the milk cannot be directly influenced in any way. It tends to vary directly with the general condition of the mother.

The percentage of protein in the milk cannot be influenced by diet. The most common cause of an excessive amount of protein is nervousness. If the mother's nervous condition can be quieted, the percentage of protein will diminish. The amount of protein can also be diminished by exercise, but if the exercise is excessive and causes fatigue, the protein will be increased. In many cases, therefore, when the woman is overtired, the protein can be diminished by rest.

Mixed Feeding.—When a woman does not have sufficient milk to satisfy her baby, the baby should not be weaned, but should be given an artificial food in addition to the breast-milk. If the supply of milk is almost sufficient, the baby may be given the artificial food entirely at one or at two feedings and the breast at the others. It is hardly ever advisable to omit more than two nursings, because the supply of milk is likely to diminish still further from lack of stimulation of the breasts, if more than this number of feedings are omitted. If there is much deficiency in the supply, the breast should be given at each feeding, followed by an artificial food. The amount of artificial food to be given depends, of course, on the amount of breast-milk. This is best determined by weighing the baby or mother before and after nursing and giving enough artificial food to make up the proper amount for a feeding. It is usually not necessary to weigh the baby before and after every feeding, once the average amount obtained from the breast has been ascertained.

No attempt should be made, in deciding on the composition of the artificial food, to imitate the composition of the breast-milk. The fact that the baby can digest human milk of a given composition does not indicate at all that it can digest a cow's milk mixture of the same composition, because, although the percentages of the

components of the two foods may be the same, the foods are different. One is human milk; the other is cow's milk, in spite of the fact that it is modified. The composition of the artificial food should be decided on general principles, based on the age and apparent digestive capacity of the infant. An analysis of the breast-milk is, however, sometimes of assistance in determining what shall be the composition of the artificial food, because in some instances, in which there is a deficiency of some element in the breast-milk, it can be corrected by an increase in the amount of this element in the artificial food.

Weaning.—A baby should not be taken off the breast unless there is a good reason for so doing. A baby should not be weaned during the early weeks of life, on the ground that the milk is unsuitable, simply because the baby has the colic and abnormal stools. It is wiser to wait until the mother is out of bed and has resumed her usual mode of life before deciding that the milk will not agree, because in many instances the symptoms of indigestion cease and the baby begins to thrive as soon as the mother gets back to her normal routine. It is important, on the other hand, not to wait too long and allow the digestion to get thoroughly upset before weaning. A baby should not be weaned hastily on account of cracked nipples. These can almost always be cured and the nursing continued.

A baby should not be weaned because of the appearance of menstruation. As a matter of fact, more women menstruate during the period of lactation than do not. In most cases the baby shows no evidences of disturbance of digestion during the menstruation; in some, the baby ceases to gain during this time and has the colic or undigested stools. A very few are seriously disturbed. They should not be weaned, however, but should be given an artificial food while the menstruation lasts and put back on the breast as soon as it is over.

Pregnancy is an indication for weaning. It is impossible for a woman to nourish three individuals, herself, a baby on the breast and another *in utero*. Someone is sure to suffer, most often the baby on the breast.

Acute disease in the mother is often an indication for weaning. If the disease is contagious, it is usually advisable to wean the baby to protect it from contagion. The younger the baby, the less likely it is, however, to contract the disease, because babies are born with a natural immunity to many of the contagious diseases. If it is not contagious, the question of nursing must be decided on the circumstances in the individual case. If the disease is a mild

one, the baby may be kept on the breast or taken off temporarily while the secretion of the breast is kept up in other ways. If the disease is a severe one, the milk will probably dry up wholly or in part and become poor in quality, so that the baby will have to be taken off the breast anyway, even if the condition of the mother warranted the continuance of the nursing, which it usually does not.

The development of a chronic disease in the mother is usually an indication for weaning. In other instances, although the baby is thriving, the strain of nursing enfeebles and debilitates the mother. The decision as to weaning in such cases must be made on the merits of the individual case, bearing in mind the fact that it is a mother's duty to nurse her baby as long as she can do it without serious detriment to herself. The older a baby is, the less dependent it is upon breast-milk. Weaning is justifiable, therefore, for slighter disturbances of the mother's health after the first few months than it would be before.

It is, unfortunately, not often necessary to decide when to wean, because the milk gives out and the baby has to be fed artificially. Under these circumstances the milk usually diminishes slowly and the baby is gradually weaned without difficulty.

If the supply of milk continues sufficient in amount, it is advisable to wean the baby when it is between ten and twelve months old. Babies rarely thrive on the breast alone more than a year, and seldom as long as this. They become anemic and, while fat, usually get flabby. The cause of the anemia is that breast-milk does not contain sufficient iron to cover the need for this substance and the iron stored in the liver at birth is usually used up before this time. If a baby is doing fairly well on the breast, it is in most instances advisable to continue nursing through the summer months, even if the baby is a year or more old in the autumn, because babies on the breast are much less liable to disturbances and infections of the digestive tract than those that are artificially fed. A baby should never be weaned in the spring to avoid weaning in the summer. The old idea that it is very dangerous to wean babies in the summer originated in the fact that babies weaned in the summer got contaminated milk and were therefore made sick, while those weaned in the spring got uncontaminated milk and were therefore less often upset. The truth of the matter is that the older a baby is, the better able it is to take an artificial food, provided that food is suitable and clean.

Babies should always be weaned slowly, if possible. It is much easier for the mother and the baby is much less likely to be made ill by the change to artificial food. If it is made ill, it can usually

be put back on the breast again without difficulty. If it is weaned suddenly and the milk is gone, as it usually is in a few days, the baby cannot get anything from the breast at first, although it may later. It is often possible to bring back the milk, by putting the baby to the breast regularly, even several weeks after breast feeding has been omitted. Weaning is much easier if the baby has been in the habit of taking one bottle a day from the beginning of nursing. This custom is advantageous for many reasons. It gives the mother far more freedom, enables her to nurse longer, gets the baby accustomed to taking the bottle as well as the breast and habituates it to the digestion of an artificial food, as well as showing what sort of artificial food it can take. If the baby has had one or more bottle feedings daily, there is usually no trouble in weaning it gradually and neither mother nor child is disturbed. If it is more than a few months old and not accustomed to the bottle, it is much harder to wean it gradually, because the baby will refuse all food except the breast-milk and cannot be starved into taking it. When the baby will not take food in any way except from the breast, and when it has to be weaned because of the mother's illness or for some other emergency, the breast feeding has to be stopped suddenly. It is best to separate the baby from its mother, but in any case some other person must give it its food. It cannot be expected to take it from its mother, whom it has been in the habit of nursing. A little baby should be given the bottle. An older baby should be fed from a glass or with a spoon. If it refuses to take food after reasonable coaxing and urging, it should be allowed to go hungry until the next feeding. Most babies will yield to the pangs of hunger after from twenty-four to forty-eight hours and take what is offered to them. Occasionally, however, a baby will not give in and it has to be forced to take food or fed with a tube to save it from starvation. Such babies should always be closely supervised because of the possibility of the development of acidosis.

When a baby has been taking one feeding of artificial food a day, there is no difficulty in deciding what food to give it. The same food is continued, the number of feedings being merely increased. When a baby that has been exclusively breast-fed can be weaned slowly, it is safe to give it a fairly strong food. It is usually possible when it is nine months or more old, to wean it directly on to a dilution of whole milk. It is also usually advisable to add starch to the mixture, because a baby of this age is perfectly capable of digesting starch and because, outside of milk, starchy foods will form the principal part of its diet for the next few months. A

mixture of three parts of whole milk and one part of a 3% barley water, giving fat 3%, sugar 3.36%, proteins 2.62% and starch 0.75%, is a reasonable one for a baby of this age. When a baby is weaned suddenly, it should always be given a weaker mixture than a baby of the given age would naturally take, in order to avoid, if possible, disturbance of the digestion from the artificial food. It is easy to strengthen the food if it agrees, difficult to correct disturbances of the digestion caused by too strong a food. The strength of the mixture must depend, largely, of course, on the age of the baby. Whey mixtures are the most suitable for young babies, mixtures with cereal diluents for older babies.

CHAPTER XII

WET-NURSES

There can be no question that the most suitable food for an infant that is so unfortunate as not to be nursed by its mother is the milk of another woman. In fact, the milk of some other woman is not infrequently better for a baby than that of its own mother, when she is nervous and feeble while the stranger is placid and strong. In former days so little was known about the artificial feeding of infants that unless a wet-nurse was obtained the prospects of survival of a baby deprived of its mother's milk were not over-bright. At present, however, on account of the great advances which have been made in artificial feeding, a normal baby can be expected to do well, if artificially fed, provided that its feeding is directed by someone familiar with the subject. Wet-nurses are not, therefore, the necessity for well babies which they were in the past. The situation is different, however, in the case of premature, feeble and ill babies. Many of these can be saved by human milk who, without it, would surely die. Many others, who eventually pull through on artificial feeding after months of illness, can be immediately restored to health by human milk. A very good rule to follow is not only never to allow a baby to die, but never to allow a baby to get into a condition in which it may die of disturbances of nutrition or of diseases of the digestive tract without getting it a wet-nurse, provided a wet-nurse can be procured.

Wet-nurses are often not an unmixed blessing in a family. They realize their own importance and not infrequently take advantage of it, causing much disturbance in the household. In general, however, they are much like other people, good, bad and indifferent. Like other people, too, how they conduct themselves depends very largely on how they are treated. Even if they do cause trouble, however, a family should be willing to put up with considerable domestic disquiet for the sake of saving their baby's life. Household worries are not to be compared with the anxiety attendant on the illness of a baby.

Every mother dislikes to have another woman nurse her baby. She should, however, in the first place, appreciate the fact that if she was fulfilling her duty to her baby, a wet-nurse would not be necessary, and in the second place, should be not only willing, but

glad, to sacrifice her own feelings for the good of her infant. There is, of course, no possibility of the transference of mental, moral or physical characteristics from the nurse to the baby. If there was, it would be far better for many babies to have wet-nurses than to nurse their own mothers. It makes no difference to the baby what is the color, race, creed, disposition or moral character of the nurse, provided her milk is of good quality and sufficient in quantity.

It is sometimes said that it is wrong to employ wet-nurses, because it is immoral to deprive one baby of its natural nourishment and give it to another. This objection is not well-founded, because women do not go out as wet-nurses for pleasure, but because they are compelled to support themselves and their babies. The wages which they earn as wet-nurses are higher than they can get in any other way and, if they board their babies out, they are enabled to board them in better places and to save money for the future. It is always advisable, however, for a nurse to have her own baby with her. Her baby can then be properly cared for, she becomes fond of it and is more likely to care for it in the future, and, if she has made a mistake, is more likely to live straight in the future for the sake of her baby. It is often an advantage to the foster baby for the nurse to have her own baby with her, because she is happier and more contented. In many instances, moreover, the foster baby is, at any rate at first, not strong enough to empty the breasts and to keep up the supply of milk. Under these circumstances, the nurse's baby can empty the breasts and keep them going. Many women are able, moreover, to nurse both babies.

Wet-nurses are often objected to on the ground of expense. This must vary, of course, with the locality and the circumstances in the individual case. It is safe to say, however, that the cost of the wet-nurse, including her board and that of her baby, will be less than that of an artificial food and the doctor's bills, which will be saved.

Qualifications of a Wet-Nurse.—A wet-nurse should be healthy and free from syphilis, tuberculosis and other chronic diseases. No woman should be accepted as a wet-nurse without a complete physical examination by a competent physician. Syphilis cannot be positively excluded, even if neither mother nor child show any evidences of it. A Wasserman test should be done, therefore, if it is practicable. Equal care should be taken to determine, however, that the baby that she is to nurse is not syphilitic. It is just as bad to have the baby infect the wet-nurse with syphilis as it is to have the wet-nurse infect the baby. It is impossible to determine from the general appearance of a woman or from the size, shape or feel-

ing of her breasts whether she has or has not a good supply of milk. Many small, thin women have much milk, and many large, vigorous-looking women but little milk. Small breasts often secrete much milk, and large breasts but little milk. The milk is secreted by gland tissue, not by fat, and it is impossible to tell by the appearance or feeling of a breast what is fat and what is gland tissue. The ease with which milk can be expressed from the breast is also unreliable as a guide, because a baby can often obtain much milk from a breast from which but little milk can be expressed, while in other instances where there is but little milk, it can all be easily expressed. The only way in which the quantity of milk which the breast is secreting can be positively determined is by weighing the wet-nurse's own baby before and after each nursing for at least twenty-four hours. Next to this is the appearance of her baby. If it is thriving, it is evident that it gets a sufficient supply of milk and that this milk is of good quality. It is useless to examine the milk to determine whether it will be suitable for another baby or not, partly because of the variation in the milk from day to day and nursing to nursing, and partly because it is impossible to know in advance whether or not a given milk will agree with a given baby.

The composition of breast-milk being the same from the end of the colostrum stage until nearly the end of lactation, it is not necessary that the foster baby and the nurse's baby shall be of the same age. It is not advisable, however, if prolonged nursing is anticipated, to take a woman as a wet-nurse who is approaching the end of the period of lactation. The only objection, however, is that her milk is likely to give out and that it will be necessary to procure another nurse. It must be remembered that if a feeble or a young baby is put to the breast of a woman with an abundance of milk, it cannot empty the breast and that, the stimulation to secretion being removed, the supply of milk will diminish and perhaps cease. Many a good nurse has been spoiled in this way and discharged as having no milk when the trouble was not with her but with the baby. It is of great advantage under these conditions for the nurse to have her own baby with her to empty the breasts. A small or young baby may be upset, also, by taking too much food from a full breast which has been nursed by an older child. This mishap can be prevented by weighing the baby before and after nursing.

Management of Wet-Nurses.—A wet nurse should be given the sort of food to which she is accustomed, and should be given the sort of work to do which she has been in the habit of doing. If a

woman that has been in the habit of doing hard, manual labor and eating plain, coarse food is given rich food and allowed to sit about, she is likely to become ill and the equilibrium of her milk is almost certain to be disturbed. On the other hand, a woman that has been in the habit of leading a sedentary life, as a seamstress, for example, and eating delicate food, cannot do hard work and eat coarse food without some disturbance of her milk resulting. Many a good wet-nurse has been spoiled by lack of attention to these details.

Methods of Procuring Wet-Nurses.—It is almost always possible to find a wet-nurse if the quest is undertaken with sufficient energy. They are most readily obtained at maternity homes and hospitals. In other instances they may be obtained through physicians and district nurses, or by advertising for them. There has been in Boston, for several years, a Directory for Wet-Nurses, where a considerable proportion of the women who wish to be nurses go. They are examined physically and the Wasserman test is done on them. The quantity and quality of their milk are also determined. They are not sent out unless they are healthy and their milk satisfactory. When they are through with one case they return to the Directory and wait for another. A reasonable fee is charged by the Directory for providing them.[1] This is the best solution of the problem in that it makes it easy to find a wet-nurse, assures the health of the wet-nurse, and is available for people living not only in the vicinity but also at a distance.

In many instances in which it is impossible for some reason to get a wet-nurse, breast-milk can be expressed from the breasts of one or several women and fed to the baby in a bottle. It makes no difference in the result whether the baby gets it directly from the breast or indirectly from the bottle. It is breast-milk just the same. The Boston Floating Hospital has, for several seasons, obtained considerable amounts of breast-milk in this way through the coöperation of several of the philanthropic and nurses' societies in Boston, and used it with good result.[2]

Breast-milk may also be preserved by freezing and used when desired. Schlossmann always has a number of wet-nurses at his hospital and during the winter months, when he does not use so much breast-milk as at other times, he saves the excess and freezes it, holding it in a refrigerator until the summer months, at which time the demand is greater. He then takes it as needed and claims very good results with it.

[1] Talbot: Journal A. M. A., 1911, vol. lvi, p. 1715.
[2] Talbot: Boston Medical and Surgical Journal, 1911, clxiv, 290.

SECTION III

ARTIFICIAL FEEDING

CHAPTER XIII

COW'S MILK. CHEMISTRY AND BIOLOGY

COLOSTRUM

The colostrum of cow's milk is never used in infant feeding, except by accident, and, for that reason, will only be treated in brief. It is probable that the explanation of the presence of the colostrum bodies in cow's milk is the same as in human milk.

Colostrum is a thick, shiny, yellowish or reddish fluid with a taste more salty than that of normal milk.[1] It is sometimes alkaline, but more often acid. The specific gravity ranges between 1.046 and 1.080, and it is richer in solids than ordinary milk. The appearance and composition gradually change during the course of a week, at the end of which time it becomes milk suitable for use.

The following analysis given by Engling [2] shows the way in which the milk changes:

TABLE 29

		Number of hours after calving				*Normal Milk*
	Immediately	10	24	48	72	
Water	73.17	78.77	80.63	85.81	86.64	87.75
Casein.....	2.65	4.28	4.50	3.25	3.33	3.00
Albumin Globulin ..	16.56	9.32	6.25	2.31	1.03	0.50
Extractives.	3.54	4.66	4.75	4.21	4.08	3.40
Sugar......	3.00	1.42	2.85	3.46	4.10	4.60
Ash	1.18	1.55	1.02	0.96	0.82	0.75

[1] Jensen's Milk Hygiene (Pearson): Phil. and London, 1907, p. 12.

[2] Taken from Jensen's Milk Hygiene (Pearson), Phil. and London, 1907, p. 30.

The fat in colostrum has a somewhat higher melting point and is poorer in volatile fatty acids than the fat in ordinary milk.[1]

The proteins in the colostrum of cows resemble those in human milk in that the greater part of them will coagulate.

COW'S MILK [2]

Appearance, Smell, Taste.—When milk is perfectly fresh, it is a white, or yellowish white, opaque fluid. It separates into two distinct layers, when it is allowed to stand undisturbed for some time. The upper and lighter layer, which consists largely of globules of fat and is called "cream," is yellower than the lower layer, which is white or bluish white and is known as "skimmed milk." When it is pure and fresh, milk has either a faint, insipid odor, or no odor at all, and a mild, faintly sweetish taste.

Microscopic Appearance.—Like human milk, it contains many minute fat droplets suspended in the form of an emulsion. There are more ultramicroscopic particles than in human milk, because it contains a larger amount of casein.

Specific Gravity.—The specific gravity of the fat in cow's milk is different in different breeds of cattle and varies between 0.922 and 0.937.[3] The specific gravity of whole milk varies between 1.028 and 1.035 at 15° C. (60. F°). Jenson gives 1.027 to 1.040).

Reaction.—The reaction depends either on the carbon dioxid and acid phosphates [4] or on the mono- and diphosphates in the milk.[5] Cow's milk is described as amphoteric to litmus paper. On standing exposed to the air, it becomes acid. The degree of the acidity and the rapidity of the change depend on the kind and on the amount of bacterial activity by which milk sugar is split up into lactic acid. Fresh milk has been studied with different indicators and it has been found that 100 c. c. of milk has the same alkaline reaction toward blue litmus as 41 c. c. of N/10 caustic soda, and the same acid reaction toward phenolphthalein as

[1] Nilson: Maly's Jahrsber. 21.

[2] The following publications are drawn from freely in the ensuing section: Kastle and Roberts: The Chemistry of Milk Hygiene, Lab. Bulletin No. 56, Washington, 1909, p. 315; Jensen's Milk Hygiene, Phila. and London, 1907, and Voltz: Chemie der Kuhmilch in Oppenheimer Handbuch der Biochemie des Menschen und der Thiere, vol. iii, first half, Jena, 1910, 386; Hammarsten A Textbook of Phys. Chemistry, N. Y., 1912; Koeppe and Raudnitz in Sommerfeld's Handbuch der Milchkunde, Wiesbaden, 1909.

[3] Heischmann: Lehrbuch der Milchvirtschaft., Heinsiws Machf., Bremen.

[4] Leach: Food Inspection and Analyses, N. Y., 1907, ii.

[5] Richmond: Analyst, 1900, xxv, 121.

19.5 c. c. of N/10 sulphuric acid.[1] Cow's milk conducts electric currents because it contains dissolved salts. Fifty-eight per cent of the molecules of the mineral salts in cow's milk and 26% in human milk are dissociated.[2]

Quantity.—Since the quantity of milk is of moment only to the milk producer, it will not be considered here.

The Coagulation of Cow's Milk.—By the coagulation of cow's milk is meant all the processes concerned in the precipitation of casein.

(a) *Effect of Acids on Coagulation of Milk.*—Perfectly fresh amphoteric milk does not coagulate on boiling. A pellicle, consisting of coagulated casein and lime salts, is formed on the surface. This reforms rapidly after being removed.[3] Fresh milk does not coagulate on boiling, even after a current of carbon dioxid has been passed through it. As milk ages, lactic acid begins to form and a stage is reached in which milk, which has previously had carbon dioxid passed through it, coagulates on boiling. At a second stage it coagulates on heating without the treatment with carbon dioxid. When the lactic acid is present in sufficient amount, the milk coagulates spontaneously at room temperature, forming a solid mass. The amount of lactic acid formed in milk depends both upon the amount of sugar in the milk and the type of organism. The acidity may vary between 0.3% and 1.3%. In most instances, when a vigorous strain of organism is used, the amount of lactic acid varies between 0.5% and 0.6%.[4]

Kastle [5] studied the coagulation of sour milk in Washington. His results are given in table 30 on page 148.

The milk which coagulated spontaneously at 65° C. (145° F.) had an acidity of 0.711. As a general rule, the milks which are most easily coagulated by heat have the highest acidity. On the other hand, samples of milk with an acidity of 0.54% of lactic acid, which did not coagulate on boiling, have been reported.[6] Fresh milk, according to Richmond,[7] has an acidity of 20 degrees, corresponding to 0.18% lactic acid. He found that milk curdled on boiling when it had an acidity of 33 degrees, corresponding to 0.29% of lactic acid.

[1] Courant: Uber die Reaction der Kuh und Frauenmilch. Inaug. Diss., Breslau, 1891, 9.

[2] Koppe: Jahrb. f. Kinderh., 1898, xlvii, 389.

[3] Hammarsten: *loc. cit.*

[4] Leischmann: Bact. acidi lactici.

[5] Kastle and Roberts: *loc. cit.*

[6] Stokes: Analyst: xvi, 22.

[7] Richmond: Analyst, 1900, xxv, 121.

TABLE 30

THE RELATION OF THE ACIDITY AND THE TEMPERATURE OF MILK TO COAGULATION (KASTLE)

Acidity per cent.	*Temp. ° C.*	*Time of heating minutes*	*Curdled* = + *Not curdled* = —
0.711	65	0	+ immediately
.594	65	1	+
.576	65	2	+
.567	65	1	+
.554	60	2	+
.531	65–67	2	+
.513	65	2	+
.478	60	5	+
.450	65	1½	+
.441	66	1	+
.387	65	5	+
.351	65–67	2	+
.342	78.5	2	+
.342	66	5	—
.315	70	10	+
.315	70	5	+
.306	75	3	—
.306	65	5	—
.288	70	5	—
.261	65–74	5	—
.252	100	1	—
.252	70	5	—
.243	100	1	—
.243	72–74	10	—
.243	65	10	—
.234	65	5	+
.225	65–67	2	
.198	65	5	—
.180	65	5	—

(b) *Precipitation with Acids.*—Casein may be precipitated from cow's milk by dilute acids. It requires 50 to 70 c. c. of N/10 hydrochloric acid, or 60 to 80 c. c. of N/10 acetic acid to give the best results. When casein is treated with dilute acids, two chemical reactions take place; first the acid combines with the calcium in the casein, forming a base-free casein or a casein set free from its combination with calcium; on the addition of more acid, the casein molecule combines directly with the acid, forming a salt of the acid. This action is hastened by an increase of temperature. (Van Slyke).

It is supposed by Van Slyke to be an absorption of acid by the

casein while Robertson believes that the acid goes in combination with the casein. Since such an excess of acid is not found in the physiology of the infant, casein may be considered as having the properties of an acid in subsequent discussions.

An excess of acid will redissolve the precipitate.[1]

(c) *Rennin Coagulation.*[2, 3]—The following are some of the more important facts in reference to the action of rennin upon milk casein in causing coagulation:

(I) The presence of soluble lime salts appears to be necessary for the coagulation of milk by rennin.

(II) The reaction must be neutral to litmus, or acid, but not alkaline. Acids, whether organic or inorganic, although they differ from one another in respect to the intensity of the influence which they exert on the action of rennin, all have a very marked effect upon the coagulation of calcium casein by rennin. The usual explanation of this effect of acids upon the action of rennin is that the acid which is added dissolves the insoluble calcium phosphate of milk and thus increases the amount of soluble calcium salts. The claim is also made by some that the acid has in itself some direct influence upon the action of rennin.

(III) The dilution of milk with water delays the coagulation of milk by rennin, because the proportion of soluble calcium salts is decreased. The addition of calcium chlorid or of a free acid to milk diluted with water not only hastens the time of coagulation, but also increases the amount of calcium coagulated.

(IV) Different chemical compounds affect the coagulation of milk by rennin in different ways.

(V) The addition of foreign, inert matter, like starch or sawdust, hastens rennin action.

(VI) The temperature affects the rapidity of coagulation of milk by rennin. For complete action, the time decreases as the temperature increases. In a given time, rennin coagulates milk most completely at from 106° to 108° F., and less completely at temperatures above and below this point.

(VII) The temperature at which coagulation takes place affects the character of the coagulum. At 60° F. the curd is flocculent, spongy and soft; at from 77° to 113° F. it is more or less firm and solid; at 122° F. and above it is very soft, loose and more or less gelatinous.

[1] Schlossmann and St. Engel in König: Der mensch. Nährungs, u. Genussmittel II, Berlin, 1914, 598.

[2] Van Slyke: Arch. Pediatrics, 1905, xxii, 515.

[3] Bosworth: Jour. Biol. Chem., 1913, xv, 231.

(VIII) Rennin heated for some time to over 140° F. becomes permanently weaker or inactive. It is somewhat affected at about 120° F. Weak solutions are more easily affected by an increase of temperature than are strong solutions.

(IX) An increase in the amount of rennin in proportion to the milk hastens the rapidity of coagulation as does also an increase in the strength of the rennin.

(X) Freshly drawn milk curdles more completely than it does after it is allowed to cool. This is because it is warmer and perhaps because of the presence of carbon dioxid.

(XI) Milk heated above 160° F. for a considerable length of time coagulates less rapidly than unheated milk. The coagulum of heated milk is highly flocculent, unless soluble calcium salts or some acid are added to it. Boiled milk is not coagulated normally, if at all, by rennin.

Hammarsten was the first to show that the coagulation of milk by rennin was due to a soluble ferment which acted directly on the casein, producing, as he thought, two substances, the insoluble curd (Kase or paracasein), and a soluble product whey-protein (Molkeneiweiss). He also showed that the change of casein to paracasein was independent of coagulation, the coagulation being due to the presence of soluble calcium salts.

A great number of papers have been published upon this subject since the early work of Hammarsten. As his explanation of the action of rennin has been generally accepted as correct, most of the recent investigations have been concerned with the influence of the soluble salts upon the coagulation. These investigations have shown that the soluble salts of calcium, barium and strontium favor or hasten coagulation, while the salts of ammonium, sodium and potassium retard or inhibit coagulation.

Recently, Van Slyke and Bosworth [1] have shown that casein and paracasein are acids having the same percentage composition; that the molecular weight of casein is probably 8,888, while the molecular weight of paracasein is one-half that of casein, 4,444; that the combinations of casein with barium or strontium are insoluble in water while the combinations with one equivalent of ammonia, sodium, or potassium are soluble; and that ammonium, sodium or potassium caseinates can be changed by rennin to paracaseinates which are soluble and are precipitated by calcium chlorid as calcium paracaseinates.

These facts seem to indicate three things:

First, that the action of rennin is the hydrolytic splitting of the

[1] Van Slyke and Bosworth: Jour. Biol. Chem., 1913, xiv, 203–236.

casein molecule into two similar molecules of paracasein; perhaps in somewhat the same manner as maltose is split into two molecules of dextrose.

Second, that it would seem doubtful if Hammarsten's whey-protein could be one of the products of rennin action.

Third, that rennin is not, strictly speaking, a coagulating ferment, the coagulation of paracasein being due to the fact that the calcium paracaseinates are less soluble than the calcium caseinates, especially in the presence of the soluble salts of calcium, barium and strontium. The coagulation is, therefore, a secondary effect, the result of a change in solubilities.

The curd formed in the coagulation of milk contains large quantities of calcium phosphate. Courant [1] believes that calcium caseinate on coagulation may carry down with it, if the solution contains dicalcium phosphate, a part of this as tricalcium phosphate, leaving monocalcium phosphate in the solution.

When the phenomena of coagulation of milk are watched under the ultra-microscope [2] the small particles of casein are seen to clump together before there is any visible gross coagulation. As more and more particles clump together they become visible. The milk of fresh cows is better suited to rennin coagulation than the milk of cows that are nearly dry.

(d) *The Effect of the Addition of Alkalies on the Curdling of Milk.*—It is necessary to bear in mind the following facts, when considering the action of alkalies on casein. Bosworth and Van Slyke [3] have shown in a pretty series of experiments that "casein is a protein showing the characteristic property of an acid, in that it combines with metals or bases to form compounds known as caseinates." For example, the compound of casein containing the largest amount of a monovolent metal-like sodium could be represented by the formula Na_8 casein (sodium caseinate); the corresponding calcium compound is Ca_4 casein (calcium caseinate). It has not been definitely settled yet which particular compound of calcium is present in milk, but it is probably either tetra-calcium or tri-calcium caseinate. When the calcium caseinate of milk is acted on by rennin, it is changed into another compound called calcium paracaseinate. As the result of this action one molecule of calcium caseinate is split into two molecules of calcium paracaseinate. This reaction may be represented in the following formula: Ca_4 caseinate = Ca_2 paracaseinate + Ca_2 paracaseinate. Para-

[1] Courant: *loc. cit.*
[2] Kreidl and Neumann: Pfluger's Arch, 1908, 123, 523.
[3] Bosworth and Van Slyke: Am. Jour. Dis. Child., 1914, vii, 298.

casein, like casein, possesses acid properties, but it only has one-half the combining power of casein. Calcium paracaseinate is less soluble than the corresponding calcium caseinate present in the milk from which it is formed, and, therefore, when milk curdles, it is precipitated as a solid. If reninn is added to a solution of sodium caseinate the caseinate is split into two molecules of sodium paracaseinate, but no precipitation or curdling takes place. This is explained by the fact that sodium caseinate is very soluble. If a small amount of a soluble calcium salt (calcium chlorid) is added to the solution of sodium paracaseinate, curdling occurs at once, the curd being calcium paracaseinate. This chemical reaction may be illustrated in the following manner:

Sodium paracaseinate (soluble) + calcium chlorid = calcium paracaseinate (insoluble) + sodium chlorid. The following table (Bosworth and Van Slyke) illustrates the effect of increasing amounts of sodium citrate on the coagulation of milk:

TABLE 31

Effect of Sodium Citrate on the Curdling of Milk by Rennin

Grains of sod. citrate to 1 oz. of milk	*Amt. rennet solution used per 100 c. c.*	*Minutes required for milk to curdle*
0.0	2.	6
0.20	2.	7½
0.40	2.	8½
0.65	2.	11
0.85	2.	31
1.00	2.	37
1.25	2.	47
1.50	2.	62
1.70	2.	not curdled
1.90	2.	not curdled
2.10	2.	not curdled

The addition of increasing amounts of sodium citrate to milk lengthens the coagulation time of the milk up to the point when 1.7 grains per ounce is added, after which the milk does not coagulate. In actual practice the addition of this amount prevents the formation of a curd in the infant's stomach. The explanation of this fact is that the sodium replaces some of the calcium in the caseinate and forms sodium caseinate of calcium-sodium caseinate. When rennin is added this double salt is changed to calcium sodium paracaseinate, which, owing to the presence of sodium, is not curdled.

Lime Water.—"When lime water is added to cow's milk until it is neutral or faintly alkaline to phenolphthalein, a basic calcium casein is formed which is not acted upon by rennet and will not form a curd even in the presence of lime salts." [1] This may be explained by the fact that casein is not coagulated by rennin when the solution is alkaline. In actual practice the addition of lime water to milk may increase its alkalinity to such a point that the stomach will not secrete the requisite amount of acid to make the stomach contents neutral or acid. A neutral or acid reaction is necessary for the coagulation of milk by rennin.

Anti-rennin may be formed by injecting rennin into horses until a ferment is formed which destroys the action of rennin.[2, 3] When it is added to milk with rennin it prevents the coagulation of milk.

The Chemical Composition of Cow's Milk.—The individual food components, fats, lactose, proteins and salts will be considered separately and then as a whole. The variations in the composition of the milk of a single cow is only of slight interest in this connection, because the milk used in infant feeding is in almost all instances mixed milk.

Nitrogenous Bodies.—The following table, compiled by Leach,[4] gives a good idea of the average amounts of the various food components and also of the extreme variations in their percentages:

TABLE 32

Cow's milk	*Specific gravity*	*Water*	*Casein*	*Albumin*	*Total protein*	*Fat*	*Lactose*	*Ash*
Minimum.....	1.026	80.32	1.79	0.25	2.07	1.67	2.11	0.35
Maximum.....	1.037	90.32	6.29	1.44	6.40	6.47	6.12	1.21
Average	1.031	87.27	3.02	0.53	3.20	3.64	4.88	0.71

Table 33 shows how much the composition of the morning and evening milk may vary. These figures are the average from 29,707 tests of milk made by Droop Richmond in England.

[1] Van Slyke: Archives of Pediatrics, xxii, 515.
[2] Hammarsten: *loc. cit.*
[3] Morgenroth: Centr. Bakt., 1900, xxvi, 349; Fuld and Spiro: Zeitschr. phys. Chem., 1900, xxxi, 132.
[4] Leach: Food Inspection and Analysis, New York, 1907. Table compiled from Koenig's Chemie der Menschlechen Nährungs und Genussmittel.

TABLE 33

Milking	*Fat per cent.*	*Lactose per cent.*	*Protein per cent.*	*Ash per cent.*	*Solids per cent.*
Morning......	3.44	4.71	3.43	0.74	12.34
Evening	3.90	4.69	3.39	0.73	12.71

Cows of different breeds give milk of somewhat different composition and, although it was supposed that cattle from mountain regions gave a richer milk than those from the lowlands, there are many exceptions to this statement.[1] The Jersey and Guernsey breeds give a rich milk and the Holstein and Ayrshire cattle are apt to give a milk poorer in fat but this is more suitable for infant feeding. The fat globules in the Jersey milk are almost three times that of the Holstein. The milk of different individuals of the same herd and species vary in composition and it is fair to assume that the production of rich milk is distinctly an "individual property that is due to the physiological peculiarities of the gland cells of the animal, and which to a great degree is hereditary." (Jensen.)

Nitrogenous Compounds.—The total nitrogenous compounds are given by Van Slyke as 3.2% and by Babcock as 3.8%. The principal proteins are casein and albumin, or insoluble and soluble proteins. The principal soluble proteins are lactalbumin and lactoglobulin. There are probably other substances also, but little is known about them. The figures as to the relation of the casein to the soluble nitrogenous bodies in the milk vary greatly, being all the way from 2.6:1 [2] to 8:1.[3] The average according to Van Slyke is 3.6 parts of casein to one part of soluble protein. (In human milk the relation is approximately 1:1.) Table 32 shows that the amount of casein and albumin in cow's milk may vary materially.

Casein.—Cow casein is a white powder, with a specific gravity of 1.259. It causes moist blue litmus paper to turn red and shows the characteristic properties of an acid, in that it combines with metals or bases to form compounds known as caseinates.[4] One gram of ash-free casein develops 5.742 calories according to Schlossmann;[5] 5.85 according to Sherman.[6] The molecular weight of

[1] See Jensen's Milk Hygiene, Phila. and London, 1907.

[2] Van Slyke: Archives of Pediatrics, 1905, xxii, 509.

[3] Stohmann: Milch und Molkereiproducte 1898, 58, quoted by Czerny and Keller; Hammarsten: Jahresber. f. Thierchemie, 1896, xxv, 206; Schlossmann: Verh. d. 13 Vers. d. Gesellsch. f. Kinderh. in Frankfurt, 1896, 78.

[4] Bosworth and Van Slyke: Am. Jour. Dis. Children, 1914, vii, 298.

[5] Schlossmann: quoted by Raudnitz in Sommerfeld's Handbuch.

[6] Sherman: Chemistry of Food and Nutrition, N. Y., 1911, 123.

casein is 8888.[1] It has the following composition: C. 53.0; H. 7; N. 15.7; S. 0.8; P. 0.85; O. 22.65%.[2]

The question whether the casein from different kinds of milk is identical or whether there are several caseins cannot be decided by the elementary composition.[2] It is probable that chemically they are much the same, but that biologically they are different. (See Human Casein.)

Casein dissolves readily in water with the aid of alkali or alkaline earths, also calcium carbonate from which it expels carbon dioxid. Such solutions are precipitated by dilute acids and redissolved by stronger acids (s. 5–2.8 grams HCL to 10.0 grains casein). It is insoluble in alcohol and water.

The casein in milk is in combination with calcium in the form of calcium caseinate. It has not been definitely settled as yet which particular compound is in milk, but it is probably either tetra-calcium or tri-calcium caseinate.[3]

Osborne and Quest [4] have shown by hydrolysis that casein contains glycocoll 0%, alanine 1.5%, valine 7.2%, leucine 9.35%, protein 6.7%, phenylalanine 3.2%, glutanine acid 15.55%, aspartic acid 1.39%, cystine series 0.5%, tyrosine 4.5%, oxyproline 0.23%, histidein 2.50%, arginine 3.81%, lysine 5.95%, tryptophan 1.5%, diaminotrioxy-dodecanic acid 0.75%, NH_3 1.61%, S. 0.76%, P. 0.85%. The figures quoted by Raudnitz [5] vary somewhat from these.

Paracasein.—Paracasein is a body closely related to casein. When paracasein is in combination with a salt the compound is known as the paracaseinate of that salt. For instance the combination with calcium is known as calcium paracaseinate. It has been shown above that calcium paracaseinate is insoluble, while sodium, potassium and ammonium paracaseinate are soluble. Calcium paracaseinate is similar to calcium caseinate, but it cannot be recoagulated by rennin.

Lactalbumin.—Lactalbumin, one of the components of whey protein, has the following composition: C. 52.19, H. 7.18, N. 15.77, S. 1.73, O. 23.13%.[2] When compared to casein, the most striking differences are that it contains more sulphur and no phosphorus.

Lactoglobulin.—Lactoglobulin is very similar in its composition

[1] Van Slyke and Bosworth: Jour. Biol. Chem., xiv, 1913, 231.
[2] Hammarsten: Textbook of Phys. Chem., N. Y., 1912, 615.
[3] Bosworth and Van Slyke: Am. Jour. Dis. Children, 1914, vii, 298.
[4] Osborne and Quest: Jour. Biol. Chem., lx, 333.
[5] Raudnitz: Sommerfeld's Handbuch der Milchkinde, Wiesbaden, 1909.

to serum globulin. It is present in only small amounts in normal milk, but in larger amounts in colostrum.[1]

Extractives.—There are traces of urea, creatine, creatinine, hypoxanthine (?) and cholesterine in cow's milk.[2]

Whey.—Whey is an opalescent solution which remains after the coagulation of casein. It contains lactalbumin, lactoglobulin and extractives. Most of the solid portion of the whey of cow's milk is lactalbumin, while the rest, a small part, is divided among the other components. Although the analyses of whey are essentially the same as the analyses of lactalbumin, they are reported in a separate paragraph. The whey from cow's milk, according to König [3] contains: water 93.8%, total ash 0.44%. The ash contains K_2O 30.77%, Na_2O 13.75, CaO 19.25, Mg 0.036, F_2O_3 0.55, P_2O_5 17.05, SO_3 2.73, CL 15.15.

Fat.—The percentage of fat in the mixed milk of herds may be maintained at 4% by carefully testing and selecting the cows. It is such 4% milk that should be used in infant feeding. The problems incident to maintaining the percentage of fats at the required amount do not concern the pediatrician, and, therefore, will not be considered.

The fat droplets are exceedingly small. Their diameter varies from 0.0024 to 0.0046 m. m. There are 1.06 to 5.75 millions of fat drops to the cubic m. m.[4] It is possible that the fat droplets are maintained in a state of emulsion because they are surrounded by a covering of casein which prevents the globules from uniting with one another,[5] or that they are surrounded by a membrane.[6]

The fat of cow's milk is chiefly of olein and palmitin. It also contains triglycerides, butyric acid, myristic acid, stearic acid, small amounts of lauric acid, arachidic acid and dioxystearic acid, as well as caproic acid, traces of caprylic acid and capric acid.[7] The fat of milk contains small quantities of lecithin, cholesterin, and a yellow coloring matter. It is possible that the quality of the food may influence the composition of the fat.

Lactose.—Milk sugar is easily soluble in water and does not ferment with pure yeast. The extreme variations in the percentage of milk sugar in cow's milk are 2.11% and 6.12%, the

[1] Sebelien: quoted by Voltz in Oppenheimer's Handb. *loc. cit.*, p. 390.
[2] Hammarsten: Textbook of Phys. Chem., N. Y., 1912.
[3] König: *loc. cit.*
[4] Woll: Wisconsin Exp. Station, vi, 1892.
[5] Quincke: Pfluger's Arch. xix.
[6] Abderhalden and Voltz: Zeitschr. f. phys. Chem. lix.
[7] Hammarsten: *loc. cit.*

average being 4.88%,[1] according to some authors, and 4.60% according to others.[2]

Lecithin.—Cow's milk contains between 0.048 gm. and 0.058 gm. of lecithin.[3]

Some investigators maintain, however, that these figures represent a mixture of lecithin and kephalin.[4]

Salts.—The total ash in cow's milk is generally given as 0.7%, the extreme limits being 0.6% and 1.0%.[5]

TABLE 34

PERCENTAGE OF SALTS IN COW'S MILK IN 100 PARTS OF ASH

	Bunge [3]	*Abderhalden* [4]	*Schloss* [4]	*Söldner*	*Pelka* [4]	*Richmond* [6]
K_2O	22.14	22.40	24.74	24.96	23.75	28.71
Na_2O	13.91	12.25	10.79	6.16	15.36	6.67
CaO	20.05	21.07	21.35	22.25	20.37	20.27
MgO	2.63	2.91	2.71	2.71		2.80
Fe_2O_3	0.04					.40
P_2O_5	24.75	24.10	29.54	32.27	27.13	29.33
(CL)	21.27	17.25	13.63	10.86	14.67	14.00

One liter of cow's milk contains in grams:

	Söldner [5]	*Schloss* [4]
K_2O	1.72–1.885	1.849
Na_2O	0.51–0.465	0.861
CaO	1.98–1.72	1.650
MgO	0.20–0.205	0.215
P_2O_5	1.82–2.437	2.183
CL	0.98–0.82	1.091

100 grams of the Ash of Cream contains in grams:[7]

K_2O	25.97	
Na_2O	9.86	
CaO	20.54	
MgO	4.20	
P_2O_5	30.23	
CL	16.15	

[1] Leach: *loc. cit.*

[2] Fleischmann: Lehrbuch der Milchwirtschaft, Bremen, 1898, xi, 43, quoted by Czerny and Keller, I, 437.

[3] Bunge: Zeitschr. f. Biologie, 1874, x, 309.

[4] Schloss: Uber Sauglings-Ernährung, Berlin, 1912, 55.

[5] Söldner: Die Landwirthsch. Versuchstat, 1888, xxxv, 361, quoted from Voltz in Oppenheimer's Handbuch, III, I, 398.

[6] Richmond: Dairy Chemistry, Phila., 1899.

[7] Schloss: *loc. cit.*

Citric Acid.—Cow's milk contains about 0.2% of citric acid.[1]

Milk conducts electric currents because of the presence of salts of various kinds. The electrical conductivity of cow's milk is 43.8.11–4, and of human milk 22.6.10-4.[2] Koppe concludes from these figures that 58% of the molecules in cow's milk and 26% of those in human milk are dissociated.

FROZEN MILK

Very little is known as to the chemical changes which take place in milk when it is frozen. It is supposed by some investigators that the casein is changed by the freezing into a more permanent compound.[3] Mai [4] concluded, however, that the freezing and thawing of milk causes no permanent change in its composition.

Pennington [5] and her collaborators found very definite changes in milk after freezing. They found that when the milk is held at a temperature of 0° C. (length of time not stated), there is proteolysis of the casein, which is primarily of bacterial origin, and proteolysis of the lactalbumin, due primarily to the native enzymes of the milk. The action of these two agents together is more rapid than that of either agent alone. The bacteria and enzymes may break down the true protein and carry the breaking down through peptones even to amino acids. There is a fermentation of lactose with the formation of lactic acid, which is largely, if not exclusively, due to bacterial action. The fat, so far as can be determined, is not affected except by the action of bacteria.

Some bacteria disappear from the milk while it is frozen, while others may increase rapidly, especially if the milk is raw. The rate of increase in the number of bacteria depends upon their previous surroundings and upon the rapidity with which they become acclimated to their surroundings. There is apt to be very little increase in the first four or five days, after which there is a very rapid increase in numbers. There is no information concerning the chemical changes which take place in milk that has been frozen from only twenty-four hours to forty-eight hours. The predominating organisms which they found were the micrococcus

[1] Söldner: Zeitschr. Biol., 1896, xxxiii, 43, 535.

[2] Koeppe: Jahrb. f. Kinderh., 1898, xlvii, 389.

[3] Engling: Landw. Vers. Stat., 1888, xxxi, 391; Siegfried and Bischoff: quoted by Raudnitz in Sommerfeld's Handbuch, 201.

[4] Mai: Z. Nahr. Genussm., xxiii, 250 from chemical abstr., Sept. 20, 1912.

[5] Pennington, Hepburn, Witner, Stafford and Burrell: Jour. of Biol. Chem., 1913, xvi, 331. See also Pennington: Jour. Biol. Chem., 1908, iv, 353; Hepburn: Jour. of the Franklin Ins., 1911, clxxii, 187.

TABLE 35

COMPARATIVE COMPOSITION OF MILKS OF DIFFERENT ANIMALS TAKEN FROM VOLTZ [1]

Milk	*Water*	*Solids*	*Fat*	*Casein*	*Total N.*	*Sugar*	*Ash*
Human	87.58	12.42	3.74	0.80	2.01	6.37	0.3 [2]
Cow	87.80	12.20	3.40	2.70	3.40	4.70	0.7 [3]
Buffalo	82.30	17.70	7.70		4.80	4.40	0.8 [4]
Zebu (1 analysis)	86.13	13.87	4.80		3.03	5.34	0.7 [5]
Lama (3 analyses)	86.55	13.45	3.15	3.00	3.90	5.60	0.8 [6]
Camel (7 analyses)	87.60	12.40	5.38	2.98		3.26	0.7 [7]
Goat	86.30	13.70	4.00	3.60	4.60	4.30	0.8 [8]
Sheep	81.50	18.50	7.00	4.30	5.60	5.00	0.9 [9]
Reindeer	67.70	32.30	17.10		10.90	2.80	1.50 [10]
Mare	90.58	9.42	1.14		2.50	5.87	0.36 [11]
Donkey	90.12	9.88	1.37	0.79	1.85	6.19	0.47 [12]
Elephant	67.85	32.15	19.57		3.09	8.84	0.65 [13]
Hippopotamus (1 analysis)	90.43	9.57	4.51				
Rabbit (1 analysis)	69.50	30.50	10.45		15.54	1.95	2.56 [14]
Guinea pig (1 analysis)	41.11	58.89	45.80		11.19	1.33	0.57 [15]
Dog (8 analyses)	77.00	23.00	9.26	4.15	9.72	3.11	0.91 [16]
Cat	81.64	18.36	3.33	3.11	9.53	4.91	0.59 [17]
Pig	82.37	17.63	6.44		6.09	4.04	0.59 [18]
Blue Whale	50.47	39.53	20.00		12.42	5.63	1.48 [19]

[1] Oppenheimer's Handbuch der Biochemie, iii, Jena, 1910, 403.
[2] J. König: D. mensch. Nährungs u. Genussmittel 1904, Berlin, ii, 598.
[3] Kirschner: Hand. d. Milchwirtschaft, Berlin, 1907, pp. 7 and 40.
[4] Kirschner (see above).
[5] König (see above).
[6] König (see above).
[7] Barthe: quoted in Malys Jahresber., 1906, 230.
[8] Kirschner (see above).
[9] Kirschner (see above).
[10] Fleischmann: Lehrb. d. Milchwirtschaft, 3rd ed., Leipzig, 1901, 67.
[11] Kirschner (see above).
[12] Kirschner (see above).
[13] Hammarsten.
[14] König (see above).
[15] König (see above).
[16] König (see above).
[17] Camaille, C. R. 63, 692.
[18] Hammarsten.
[19] Backhans quoted in Maly's Jb. 1906, 299.

aurantiacus (Cohn), and the micrococcus ovalis (Escherich) both of which belong to the acid forming group.

Rosenau [1] found that freezing milk for forty-eight hours did not influence its restraining action on the growth of the typhoid bacillus, but destroyed it for the B. lactis aërogenes.

GOAT'S MILK

Goats are seldom infected with tuberculosis.[2] This does not mean, however, that they are immune and never have the disease.

The goat may secrete ten times its own weight in milk in a year's time.[3] It produces the most milk during the hot summer months.

The composition of goat's milk as given by various authors is as follows:

TABLE 36

Per cent. of	*Ellenburger* [4]	*Hucho* [5]	*Abderhalden*[6]	*Voelcker* [7] 1	2	3	*Anderegg* [8]	*Schaffer* [9]	*Steinegger*
Fat	6–7	2.50 to 5.10	2.93	7.02	7.11	7.34	4.6	2.14 to 4.72	3.25
Lactose...	4.5	3.76–5.46	3.92	5.28	4.68	5.99	4.3	2.07 to 4.77	2.80
Casein....	2.8		2.56						
Albumen..	0.51		0.58				1.03		
Total protein .	3.35	2.25–3.89	3.14	4.67	3.94	3.19	3.5	2.3 to 4.38	3.92
Ash	0.895	0.72–0.98		1.01	0.79	0.77	0.51–0.93	0.63	0.63

The composition of goat's milk is very similar to that of cow's milk. It is different, however, in that it is pure white instead of golden white in color. Goat's milk has a characteristic odor when it is milked in the stable and the odor of the animals pervades the

[1] Rosenau: Hygienic Laboratory, Bulletin No. 56, Washington, 1909, 487.

[2] Richter: Berliner klin. Wochenschr., 1888, No. 18; Schwartz: Deutschr. med. Wochenschr., 1896, No. 40.

[3] Fleischmann: Lehrbuch d. Milchwirtschaft, 2nd ed., 1898, 65 (C. & K.)

[4] Ellenburger: Arch. f. physiol., 1899, p. 48.

[5] Hucho: Yahresber f. physiol. Chemie, 1899, xxvii, 440.

[6] Abderhalden: Zeitschr. f. physiol. Chemie, 1899, xxvii, 440.

[7] Voelcker: Milchzeitung, 1881, x, 151 (3 goats).

[8] Anderegg: Sandw. Wochenbl., 1893, xix, 290 and 330 (C. & K.)

[9] Schaffer: Schweizer, Wochenschr., f. Pharmacie, xxxi, 58 (C. & K.)

air. This odor is more marked when the male is present in the same stall as the female.

The fat drops in goat's milk are somewhat smaller than those in cow's milk. The casein coagulates more quickly with rennin than does that of cow's milk.[1] The casein precipitates out in compact masses, which are colored white and have a fine structure. When this casein undergoes pepsin-hydrochloric acid digestion, 12% remains undigested.

König [2] found the average composition and the extreme variations in 100 analyses to be as follows:

TABLE 37

	Average	*Variations*
Water	86.88 %	82.02 -90.16%
Fat	4.07 %	2.29 - 7.55%
Lactose	4.63 %	2.80 - 5.72%
Protein	3.76 %	3.32 - 6.50%
Ash	0.85 %	0.35 - 1.36
Specific gravity	1.030%	1.028- 1.036

The composition of goat's milk is influenced by the same factors and in the same manner as cow's milk.

[1] Devarda: Landw. Versuchsst. xlvii, 416; Steinegger: Milch Ztg., 1898, No. 23. Quoted by Burr in Sommerfeld,—*loc. cit.*

[2] König: Molkerei-Ztg. Hildesheim, 1897, pp. 617, 635, 653.

CHAPTER XIV

COW'S MILK: BACTERIOLOGY AND CHEMICAL TESTS[1]

There are two types of bacteria found in milk, the non-pathogenic and the pathogenic. The ideal milk would be one which contained no bacteria but this is very difficult to obtain because bacteria find their way into the udder through the opening in the teat. These bacteria are washed out in the fore-milk which is rejected for this reason, by those producing clean milk.

The commonest bacteria in milk are those producing souring, of which the lactic acid bacteria are the most common. These bacteria produce so much acid in milk that they gradually crowd out other organisms which cannot grow in the acid surroundings. Lactic acid bacteria are not found in milk when it leaves the udder, but enter the milk when it is exposed to air. The commonest lactic acid forming bacteria are the Bacillus lactis acidi or Streptococcus lacticus. They grow best in anaërobic media. A less common form is the B. lactis aërogenes.

Of the bacteria which may produce disease in man and cause souring of milk, the colon bacillus is common. It is derived from the manure of the cow. Streptococci, which cause inflammation of the udder of the cow, may sour the milk and cause disease in those drinking it. There are some one hundred varieties of bacteria which may lead to lactic acid fermentation and souring of milk.

The class of organisms known as putrefactive bacteria may impart a bad odor to the milk and cause diarrhea in children either through their own action or by the products of their activity. They enter the milk in manure and filth. They may liquefy and digest casein.

Another group of bacteria apparently has no action on the milk and is not harmful to the consumer.

Butyric acid bacteria form butyric acid by splitting up the fat in rancid butter. Yellow, red, blue, brown and green milk are rarely seen and the particular coloration is due to changes produced in the milk by special bacteria. A turnip taste is often given milk by the B. fœtidus lactis. Slimy milk, and bitter, stringy, and soapy

[1] Winslow: The Production and Handling of Clean Milk, New York, 1909, has been freely used in this section.

milk are due to other special bacteria. Bitter milk may, however, be produced by other causes than the growth of bacteria, as by certain foods which the cow may eat (lupines, ragweed, wormwood, cabbages, raw Swedish turnips). Inflammation of the udder or garget may also cause the milk to be bitter.

Red milk may be due either to blood or the cow's eating large amounts of sedges, rushes, madder root, alkalet, field horsetail, meadow saffron, and knot grass. A red yeast may cause the cream to turn pink after standing two days.

Slimy milk may be due to pus or to the B. lactis viscosus, which comes chiefly from water and dust.

Pathogenic Bacteria in Cow's Milk.[1]—The tubercle bacillus is found frequently in cow's milk when the animal is affected with tuberculosis of the udder. It is also found in milk when the udder is healthy and there is disease in other parts of the body, viz., if the bowel or uterus, the excretions of which fall into the milk. The secretion from a diseased lung is swallowed and may be spattered into the milk pail. The tubercle bacillus may also get into milk from consumptives who are working around the cattle, either from their hands or expectoration.

Theobald Smith [2] and others have shown that there is a difference between the human and bovine type of the tubercle bacillus. Recent pathological investigations show that the bovine type of the tubercle bacillus may be the cause of tuberculosis in human beings, especially in the infant and young child.[3]

Other pathogenic bacteria which may grow in milk and have been the etiological cause of epidemics are the typhoid bacillus, the diphtheria bacillus, the streptococcus, and the organism that causes scarlet fever. The milk is usually infected after it has been milked by the hands of the milker, the air and dust in the stable, the milk pail, the water supply, the milk cooler, cans or bottles. The organisms get into the milk from the outside.

Other organisms which have not been reported as the cause of epidemics, but which are of pathological significance in cow's milk are the dysentery bacillus (both Shiga and Flexner types), the gas bacillus, the staphylococcus, bacteria of the colon group, the bacillus of anthrax, actinomyces, and the organisms of cow pox, hydrophobia, foot-and-mouth disease and cholera.

[1] Weber, A.: In Sommerfeld's Hand. der Milchkunde, Wiesbaden, 1909, 405, is used freely in this section. The original may be consulted for the literature.

[2] Smith, Theobald: U. S. Dep't Agric. Bureau of Animal Ind., 12 and 13, Washington, 1897; Jour. Exp. Med., 1893, iii.

[3] Von Behring and Smith, T.: British Royal Commission on Tuberculosis.

"Milk sickness" [1] is a disease of sparsely settled communities which has been described only in America. It is due to a motile rod with flagella, the Bacillus lactimorbi, which has been demonstrated by Jordan and Harris.[2] In cattle it causes the disease known as "trembles." It is very fatal to man.

The bacillus of contagious abortion [3] has recently been studied in milk, but its pathological significance to man is as yet unknown. Larson and Sedgwick [4] have found that the blood of many women who have aborted gives the complement fixation test to the Bacillus abortus as does the blood of many children.

Caloric Value of Milk.—It is obvious that the caloric value of milk depends upon its composition. Since the composition of cow's milk varies considerably the caloric value also varies. The figures most generally accepted are those of Rubner who found that 1000 grams of milk gave between 622 and 690 calories. Heubner uses 670 calories as the average caloric value of cow's milk.

Milk Preservatives.[5]—The most commonly used preservatives are formaldehyde, borax and boric acid. Occasionally salicylic acid and sodium carbonate are employed.

Formaldehyde may be detected in milk in the following manner: Place about twenty cubic centimeters of milk in a small glass vessel, dilute with an equal volume of water, and add commercial sulphuric acid, allowing it to flow slowly down the inside of the vessel. If formaldehyde is present a purple color will appear at the junction of the acid and milk.

Boric acid or borax are detected by adding a drop or two of hydrochloric acid to a few drops of milk in a white dish and then several drops of a saturated alcoholic solution of turmeric. The dish is then heated gently for a few minutes and, if boric acid or borax are present, a pink or dark red color will appear. A dark blue-green should appear when the dish is cooled and a drop of ammonia added.

Sodium carbonate is detected by adding an equal volume of alcohol and then two drops of a 1% solution of rosolic acid to the suspected sample of milk. If sodium carbonate is present a red-rose color will appear. The test may be performed with more

[1] McCoy: Treasury Dep't, Hygienic Laboratory Bull. 56, Wash., 1908, 217.

[2] Jordan and Harris: Jour. A. M. A., 1908, L. 1665.

[3] Fabyan: Jour. of Med. Research, xxvi, No. 3; xxviii, No. 1; Larson: Jour. Inf. Dis., 1912, 178.

[4] Larson and Sedgwick: Am. Jour. Dis. Children, 1913, vi, 326.

[5] Taken from K. Winslow: The Production and Handling of Clean Milk, N. Y., 2nd Edition, 1909.

certainty if a control test is made at the same time with a sample of milk known to be pure.

Salicylic acid is rarely used as a preservative. It may be detected by adding a few drops of sulphuric acid to a small quantity of milk and then shaking gently with a mixture of equal parts of ether and petrolic ether. Equal volumes of acidulated milk and the ether mixture should be taken. The upper ethereal solution is poured off after standing for several hours and the remaining liquid is evaporated in a porcelain dish. A few drops of water and a drop of ferric chlorid solution will produce a violet or purple color on being added to the solution if salicylic acid is present.

Babcock test (see page 216).

Estimation of total solids (see page 216).

CHAPTER XV

STERILIZATION, BOILING AND PASTEURIZATION OF MILK

The term, "sterilization," should never be applied to the processes used in the preparation of milk for the feeding of infants, because the milk is never rendered bacteriologically sterile by them. The term "pasteurization," as it is ordinarily used, is indefinite and misleading. It should always be stated at what temperature the milk is heated and how long it is kept at this temperature; otherwise, it means nothing.

THE CHANGES PRODUCED IN MILK BY HEAT

Appearance, Taste and Smell.—A well-marked scum, or pellicle, develops on the surface of boiled milk. This may begin to develop at as low a temperature as 122° F. (50° C.) (Pfaundler and Schlossmann).[1] This is due to the disassociation of the casein compounds as the result of drying. Its composition is:

Fatty matter	45.42%
Casein and albuminoid	50.86%
Ash	3.72% (Rosenau)

Changes in the taste and smell may develop at as low a temperature as 158° F. (70° C.) (Sommerfeld),[3] but are usually not marked unless the milk is brought nearly to the boiling point. Prolonged boiling changes the color toward brown, the amount of change depending on the duration of the boiling. The change in color is due to the caramelization of the sugar. Heating at 150° F. (65° C.), or over, for half an hour, materially delays or entirely prevents the rising of cream. This is because the normal agglutination of the fat droplets is broken down and they are more homogeneously distributed throughout the fluid (Rosenau).[2]

[1] Pfaundler and Schlossmann: The Diseases of Children, 1908, i, 303.

[2] Rosenau: Bulletin 56, Hyg. Lab., Pub. Health Service, 1909; Circular 153, U. S. Dept. Agric., Bureau of Animal Industry, 1910.

[3] Sommerfeld: Handbuch der Milchkunde, J. F. Bergman, Wiesbaden, 1909.

Composition.—When milk is boiled there is a partial fixation of the calcium salts, which are probably precipitated in the form of tricalcium phosphate (Kastle and Roberts).[1] There is also a precipitation of the magnesium salts (Rosenau).[2] There is a diminution in the amount of organic and an increase in that of inorganic phosphorus (Rosenau).[2] About one-third of the citric acid is precipitated in the form of tricalcium citrate (Pfaundler and Schlossmann.[3] About 90% of the carbon dioxid and 50% of the oxygen and nitrogen are also driven off (Pfaundler and Schlossmann).[3] There is also a certain amount of decomposition of the compounds of casein into casein and its base. The casein is rendered less easy of coagulation by rennin and is more slowly and imperfectly acted on by pepsin and pancreatin (Rosenau).[2] It is difficult to understand why this is so, because the precipitation of the soluble albumins, which act as protective colloids (Alexander and Bullowa),[4] by boiling, should make the coagulation of the casein easier. The curd produced by the action of acids (Pfaundler and Schlossmann) [3] and rennin (Rosenau) [2] is, moreover, softer and more flocculent than that in raw milk. The soluble albumins are entirely precipitated (Sommerfeld).[5]

There are no available data as to the temperature at which the changes which take place in boiled milk first appear, except in the case of the soluble albumins. Sommerfeld [5] quotes Steward to the effect that heating at 149° F. (65° C.) for thirty minutes diminishes them, and that thirty minutes at 176° F. (80° C.) completely destroys them. Schlossmann [6] found a slight diminution in the solubility of the albumins at 158° F. (69° C.) and Solomin [7] states that there is an "apparent" beginning of clotting of milk albumin by heating at 140° F. (60° C.) for fifteen minutes, but he is not sure whether or not it is really the lactalbumin which is involved. It is not far wrong to conclude, therefore, with Hippius,[8] that the heating of milk at 149° F. (65° C.) for thirty minutes causes no noteworthy changes in the chemical composition of the milk.

Ferments.—According to Hippius,[8] the proteolytic ferment of cow's milk is unchanged by heating for one hour at 140° F.

[1] Kastle and Roberts: Bulletin 56, Hyg. Lab., Pub. Health Service, 1909.

[2] Rosenau: Bulletin 56, Hyg. Lab., Pub. Health Service, 1909; Circular 153, U. S. Dept. Agric., Bureau of Animal Industry, 1910.

[3] Pfaundler and Schlossmann: The Diseases of Children, 1908, i, 303.

[4] Alexander and Bullowa: Arch. Pediat., 1910, xxvii, 18.

[5] Sommerfeld: Handbuch der Milchkunde, J. F. Bergman, Wiesbaden, 1909.

[6] Schlossmann: Ztschr. f. physiol. Chem., 1896–7, xxii, 197.

[7] Solomin: Arch. f. Hyg., 1897, xxviii, 43.

[8] Hippius: Jahrb. f. Kinderheilk., 1905, lxi, 365.

(60° C.) or for one-half hour at 149° F. (65° C.), but is destroyed by boiling, while the oxidizing ferment is unchanged by heating, even for several hours, at from 140° F. (60° C.) to 149° F. (65° C.), but is destroyed by one hour at 169° F. (76° C.). Kastle and Porch [1] have shown, moreover, that the peroxidases are somewhat increased by heating at 140° F. (60° C.).

Bactericidal Action.—The bactericidal power of milk is still considerable after continued exposure to temperatures of from 140° F. (60° C.) to 149° F. (65° C.), but is destroyed by boiling (Hippius).[2] The alexins are affected in the same way (Von Behring).[3]

Precipitin Reaction.—The heating of milk, even for one hour at 248° F. (120° C.) in the autoclave, does not diminish the precipitin reaction (Hippius).[2]

Bacteria and Their Products.—It has been proved by many investigators that the typhoid bacillus, the diphtheria bacillus, the dysentery bacillus and the cholera vibrio, as well as the other pathogenic non-spore-bearing organisms most often found in milk, are destroyed in milk by heating at 140° F. (60° C.) for twenty minutes (Rosenau) [4] and at higher temperatures for shorter lengths of time. Butyric acid bacteria are destroyed at from 212° F. to 216° F. (100° C. to 102.2° C.) for from one to two minutes (Sommerfeld).[5] The spores of the peptonizing bacteria are much more resistant, however, some of them withstanding boiling for one hour (Sommerfeld).[5]

Since the investigations of Flügge,[6] in 1894, who found spore-bearing peptonizing bacteria developing in milk heated at 158° F. (70° C.) for thirty minutes and forming highly toxic substances therein, it has been very generally believed that the destruction of the lactic acid bacteria by pasteurization resulted in the unhindered growth of undesirable, proteolytic bacteria, which produced toxins and other poisonous products, and that pasteurized milk putrefied rather than soured. It has also been supposed that bacteria multiply more rapidly in pasteurized than in raw milk. Ayers and Johnson [7] recently found, however, that many acid-

[1] Kastle and Porch: Jour. Biol. Chem., 1908, iv, 301.

[2] Hippius: Jahrb. f. Kinderheilk., 1905, lxi, 365.

[3] Von Behring: Therap. d. Gegenw., 1904, N. F., vi, 1.

[4] Rosenau: Bulletin 56, Hyg. Lab., Pub. Health Service, 1909; Circular 153, U. S. Dept. Agric., Bureau of Animal Industry, 1910.

[5] Sommerfeld: Handbuch der Milchkunde, J. F. Bergman, Wiesbaden, 1909.

[6] Flügge: Ztschr. f. Hyg., 1894, xvii, 272.

[7] Ayers and Johnson: Bulletin 126, U. S. Dept. Agric., Bureau of Animal Industry.

forming bacteria are not destroyed below 168° F. (75.6° C.) and that, in consequence, pasteurized milk turns sour in the same way as raw milk, although the process is somewhat delayed. They found that there were fewer peptonizing bacteria in pasteurized than in raw milk and that they did not multiply rapidly. The numerical relations of the acid-forming bacteria, the peptonizing (putrefactive) bacteria and the inert bacteria were practically the same as in clean, raw milk, and the acid development in an efficiently pasteurized milk was about the same as in clean, raw milk. They also found that the rate of multiplication of bacteria depended on the number of bacteria present in the milk. The rapidity of multiplication was the same in pasteurized as in raw milk containing the same number of bacteria and more rapid in both than in dirty milk.

It is generally believed that the heating of milk, even to boiling, has no effect on the toxic products of bacterial growth which it may contain. This belief is in part justified and in part unwarranted. The true bacterial toxins are thermolabile, many of them being rendered inert at 140° F. (60° C.). Bacterial endotoxins may be very resistant, however, that of the B. coli communis being, for example, unaffected by fifteen minutes at 272° F. (134° C.). There is no doubt that the spore-bearing organisms can set up putrefactive and proteolytic changes in milk and produce poisons as the result. The nature of these poisons is not known. Their connection with "milk poisoning" has been inferred, not demonstrated. Moreover, as far as is known, the true bacterial toxins play but little, if any, rôle in milk poisoning (Rosenau).[1]

THE EFFECTS OF THE HEATING OF MILK ON ITS DIGESTIBILITY AND ON ITS VALUE AS A FOOD FOR INFANTS

Experiments in Artificial Digestion.—The evidence derived from artificial digestion experiments as to the comparative digestibility of boiled or sterilized and raw milk is inconclusive; there is little or none as to that of pasteurized and raw milk. The casein is rendered less easy of coagulation by rennin, but the curd produced by the action of acids (Pfaundler and Schlossmann) [2] and rennin (Rosenau) [1] is softer and more flocculent than that in raw milk. De Jager [3] concluded that raw milk was the more

[1] Rosenau: Bulletin 56, Hyg. Lab., Pub. Health Service, 1909; Circular 153, U. S. Dept. Agric., Bureau of Animal Industry, 1910.

[2] Pfaundler and Schlossmann: The Diseases of Children, 1908, i, 303.

[3] DeJager: Centralbl. f. d. med. Wissensch., 1896, xxxiv, 145.

easily digested, while Fleischmann [1] decided that sterilized milk was more easily acted on by the digestive ferments than raw milk. Jemma [2] and Michael [3] found that sterilization did not impair the digestibility of milk.

Animal Experiments.—Almost all experiments agree in showing that all animals do better when fed on the raw than on the cooked milk of their own species. Von Brünning [4] has collected reports of experiments of feeding animals with the raw and cooked milk of another animal. The results were the same in all, namely, that, when fed on the milk of another animal, the young animals did better when the milk was cooked than when it was raw. Raudnitz [5] fed dogs on raw and on sterilized milk and found that the fat and nitrogen were better utilized with the raw than with the sterilized milk. Lane-Claypon [6] has reviewed the literature of this subject very carefully and done considerable experimental work herself. She concludes from her own work that there is no evidence to show that, in the case of calves, boiled cow's milk is inferior to raw cow's milk and that, if young animals are fed upon the milk of a suitable foreign species, they appear to thrive somewhat better if the milk is given boiled than raw.

Experiments on Babies.—Lane-Claypon [6] has recently summed up the work which has been done in feeding babies on raw and cooked human milk and arrives at the conclusion that the data available are insufficient to warrant any definite decision as to the comparative nutritive value of raw and boiled human milk for babies. There is no doubt, however, that many babies thrive well on boiled human milk.

Very few metabolism experiments have been done in babies as to the relative utilization of raw and cooked cow's milk and these are incomplete and fragmentary. They show, however, little difference in the results with the two foods. Müller and Cronheim [7] found that the calcium was less well utilized when the milk was cooked, but Finkelstein [8] says that their methods are open to

[1] Fleischmann: Quoted by Doane and Price, Bulletin 77 of the Maryland Agricultural Experiment Station, 1901.

[2] Jemma: Dietet. and Hyg. Gaz., 1900, xvi, 83

[3] Michael: Hyg. Rundschau, 1899, ix, 200.

[4] Von Brünning: Quoted by Finkelstein. See note 8.

[5] Raundnitz: Ztschr. f. physiol. Chem., 1890, xiv, 1.

[6] Lane-Claypon: Report to Local Government Board, England, N. S. No. 63.

[7] Müller and Cronheim: Therap. Monatsh., 1903, xvii, 340.

[8] Finkelstein: Therap. Monatsh., 1907, xxi, 508.

criticism. Krasnogorsky,[1] on the other hand, states that the iron is better utilized from cooked than from raw milk.

It has been generally believed in this country until very recently that babies fed continuously on cooked milk do not thrive so well as those fed on raw milk and that the cooking of milk predisposes to the development of the diseases of nutrition, while physicians in Europe have believed that babies thrive as well, or perhaps better, on cooked than on raw milk. There is, however, relatively little evidence on either side. Finkelstein [2] studied sixty well and fifty-three sick babies and concluded that there was no evident difference in the results with raw and with cooked milk and that neither the gain of the healthy nor the healing of the sick was visibly aided by raw milk. He quotes Czerny as having obtained the same results and states on the authority of an oral communication that the experiment of feeding raw and cooked milk to a large series of babies had been tried for three years at the Waisenhaus in Stockholm and that no difference in the results from the two methods had been noted. Variot [3] states that during the twelve years ending in 1904 more than 3,000 infants were fed at the dispensary of the *goutte de lait* of Belleville with milk heated at 226° F. (108° C.) and that rachitis did not develop in any, but that anemia was not uncommon. Scurvy is not mentioned. Carel [4] states that of 210 infants belonging to the laboring class of Paris fed on raw milk, 31.8% developed rickets, while of 373 infants of the same class fed on cooked milk only 15% developed rickets and none scurvy. Sill [5] of New York reports, on the other hand, that he found signs of rickets or scurvy in 97% of 179 consecutive cases of infants fed on pasteurized or sterilized milk. The statistics of the French observers are open to considerable doubt, however, because, unless the French infants of the hospital class are very different from the American, 80% of them show signs of rickets, no matter on what they are fed, while scurvy was not sufficiently well known in France at that time to be recognized unless of a most extreme type. Lane-Claypon [6] has recently studied a series of babies, part of whom were fed on breast-milk and part on boiled cow's milk, at the Municipal Infant Consultation in the Naunyn Strasse in Berlin. She found that the deficit in weight in the babies fed on

[1] Krasnogorsky: Jahrb. f. Kinderheilk., 1906, lxiv, 651.

[2] Finkelstein: Therap. Monatsh., 1907, xxi, 508.

[3] Variot: Compt. rend. Acad. d. Sc., 1904, cxxxix, 1002.

[4] Carel: Le lait sterilisé, Thèse de Paris, 1902–3.

[5] Sill: Med. Rec., New York, 1902, lxii, 1016.

[6] Lane-Claypon: Report to Local Government Board, England, N. S. No. 63.

boiled cow's milk below those fed upon the breast was not as much as 10% at any period. She also sums up the literature of the subject in her paper.

It is very difficult to determine what influence the heating of milk, at whatever temperature, has on the development of rickets, because the exact etiology of rickets is at present so obscure. It is probable that heredity, improper hygienic surroundings and improper food all play a part in its production. It is extremely difficult to know in an individual case which is the most important element and almost impossible to determine it in large series of cases. Our present statistics as to the relative frequency of rachitis in those fed on heated and those fed on raw milk are not accurate enough to form the basis of any definite conclusions on this point, because they do not give any accurate data as to the other possible etiologic conditions.

The evidence to prove that the heating of milk produces scurvy is stronger than in the case of rickets, but not at all conclusive, this evidence being the fact that all large series of cases of scurvy show that a considerable proportion of the patients were fed on heated milk, more of them, however, on sterilized, boiled or scalded, than on pasteurized milk. It is impossible to prove, however, that it was the heating of the milk and not the composition of the food which caused the scurvy in these babies. It is evident that when an individual baby is fed on a heated, modified milk it is impossible to know, if scurvy develops, whether it is due in the special case to the heating or to the composition of the milk. It can be only a matter of opinion. A decision can be reached only by the analysis of large series of cases. It may even then be difficult, as is shown by the fact that the series collected by the American Pediatric Society, the largest single series on record, is quoted both for and against the etiologic influence of the heating of milk in the production of scurvy. Further evidence against the heating of milk causing scurvy is that scurvy sometimes develops in the breast-fed and in babies fed on raw milk. Still further evidence are Plantenza's [1] observations that, although scurvy developed more frequently in babies fed on heated milk which was not used at once than on raw milk, it did not develop when fresh milk was heated and used at once.

It has been asserted that the cooking of milk "devitalizes" it and thus renders it a less suitable food for infants. It is presumable that what is meant by "devitalization" is the destruction of the ferments. The point at which this occurs has already been

[1] Plantenza: Arch. f. Kinderheilk., 1912, lviii, 155.

given, showing that they are not injured at temperatures below 150° F. (65° C.). There is no proof, however, that the ferments of milk play any part in the digestion and utilization of the milk, the only apparent foundation for the belief that they do being a statement of Marfan[1] in 1901 that "it is probable that the milk ferments act as stimulators and regulators of nutrition, and that they are identical in function with the ferments elaborated by the various tissues and are intended to compensate for the deficiency of the internal secretions of the new-born." This statement is founded entirely on analogies and hypotheses and not on experiments or facts.

Cooking of Milk Advised as a Routine Measure.—The boiling and proper pasteurization of milk destroys the ordinary non-spore-bearing pathogenic microörganisms. The bacterial growth in pasteurized milk is the same as in clean, raw milk. The evidence at present available is insufficient to show whether cooked milk is more or less digestible than raw milk, whether babies thrive on it as well as on raw milk and whether or not it predisposes to the development of the diseases of nutrition. Granting that the cooking of milk does make it somewhat less digestible and that its continued use does predispose to the development of the diseases of nutrition, it is evident, nevertheless, that the disturbances which it causes are slight and insignificant in comparison with the diseases caused by milk contaminated with bacteria. All milk, except the cleanest, should, therefore, be cooked before being used as a food for infants.

Pasteurization.—The higher the temperature at which milk is heated, the greater are the changes in its composition. While it is somewhat problematical how much influence these changes have on the development and well-being of the infant, it is the part of wisdom to avoid them as far as is consistent with the attainment of the object of cooking milk, that is, the destruction of pathogenic microörganisms. Pasteurization is therefore preferable to boiling. The temperature of the pasteurization should be, moreover, as low as is possible. Pasteurization at 140° F. (60° C.) for twenty minutes is efficient; lower temperatures are not. This temperature and time are, therefore, the ideal ones. At this temperature there is no change in the taste, odor or color of the milk, no noteworthy changes in the chemical composition are produced, the ferments and bactericidal action are unaffected and bacterial toxins and nonspore-bearing microörganisms are destroyed.

There are three methods of commercial pasteurization in com-

[1] Marfan: Presse Méd., 1901, ix, 13.

mon use: the flash method, the holding method and pasteurization in the bottle. The flash method consists in momentarily heating the milk to a temperature of approximately 170° F. (76.7° C.) by allowing it to flow in a film over heated metal pipes or coils and then at once chilling it. The holding method consists in heating the milk to between 140° F. (60° C.) and 155° F. (68° C.) and then placing the milk in a receptacle where it is held at approximately this temperature for from twenty minutes to an hour. The flash method has been repeatedly shown to be unreliable and should not be employed. The holding method is not so satisfactory as would at first appear, because, while the destruction of the bacteria in a small quantity of milk by heating it at 140° F. (60° C.) for twenty minutes is simple enough, it is very difficult to heat a large volume of milk to a definite temperature and hold it at that temperature for a given period of time. Schorer and Rosenau [1] have shown that under ordinary commercial conditions the temperatures expected were not attained. In their four experiments, two planned for 140° F. (60° C.) and two for 145° F. (62.7° C.), from 99.4% to 99% of the bacteria were, nevertheless, destroyed. A certain number of pathogenic microörganisms, however, survived. They conclude, therefore, that in order to be safe, pasteurization under commercial conditions should be at 145° F. (62.7° C.) for from thirty to forty-five minutes. Schorer [2] further concludes that the safest method for pasteurization is in the sealed bottle, allowing at least thirty minutes for heating to the temperature of pasteurization and then pasteurizing at 145° F. (62.7° C.) for thirty minutes. He also wisely advises that all commercial pasteurization shall be carried out under official supervision.

It must never be forgotten that the pasteurization of milk does not do away with the necessity of taking care of it and keeping it cold. It is just as important to keep pasteurized milk oold as it is to keep raw milk cold, because pasteurization simple diminishes the number of microörganisms. It does not destroy them entirely.

While it is easier to approach laboratory methods in the home than under commercial conditions, it is wiser to adopt 145° F. (62.7° C.) for thirty minutes as the standard instead of 140° F. (60° C.) for twenty minutes, in order to be sure that the pasteurization is efficient. The changes produced in the milk at this temperature and time are little, if any, greater than at the lower temperature and shorter time.

It is not necessary to have any special apparatus for the pasteur-

[1] Schorer and Rosenau: Jour. Med. Res., 1912, xxvi, 127.

[2] Schorer: Am. Jour. Dis. Child., 1912, iii, 226.

ization of milk in the home, as any dish of sufficient size and depth will do. Each feeding should be placed in a separate, clean, boiled bottle. The bottle should then be tightly stoppered with non-absorbent cotton and placed in a pail or dish of cold water, the water in the dish being at the level of the milk in the bottle. The dish should then be placed on the stove and heated until the thermometer, suspended in the water, reaches 145° F. (62.7° C.). The dish and its contents should then be taken off the stove and covered with a blanket. It should be allowed to stand for thirty minutes. The bottles should then be taken out, cooled quickly, preferably in running water, and kept in a cold place until used.

There are several pasteurizers on the market, designed for home use, which are more convenient, although no more efficient. That sold by the Walker-Gordon Laboratory is a good one. Another, designed by Dr. R. G. Freeman of New York, although working on a little different principle, is very satisfactory.

CHAPTER XVI

CERTIFIED MILK

Certified milk is the product of dairies operated in accordance with accepted rules and regulations formulated by authorized medical milk commissions to insure its purity and adaptability for infants and invalids. The methods and standards for the production and distribution of certified milk adopted by the American Association of Medical Milk Commissions, May 1, 1912, are in brief as follows:

The surroundings of all buildings shall be kept clean and free from accumulations of dirt of all sorts, and the stable yards shall be well drained. The pastures shall be free from marshes, stagnant pools or streams which may be contaminated. The buildings shall be so located as to afford proper shelter and drainage and relative freedom from dust. The stables shall be so constructed as to facilitate the prompt and easy removal of waste products. The floors shall be of non-absorbent material and the gutters of cement. All interior construction shall be smooth and tight. The drinking and feed troughs shall be cleaned daily. The stanchions shall be provided with throat latches. The stables must be provided with adequate ventilation, each cow having at least 600 cubic feet of air space, with 2 ft. square of window area for each 600 cubic feet of air space. Flies, vermin and other animals shall be excluded from the buildings. The bedding must be clean and dry. The soiled bedding and manure shall be removed at least twice daily. Manure shall not be even temporarily stored within 300 feet of the barn or dairy building. Cleaning of the barn shall be done at least an hour before milking time. The cows shall be groomed daily, and the hairs about the udder and tail clipped short. The udders and teats shall be cleaned, washed with a cloth and water and wiped dry with another clean sterilized cloth, before milking. Foodstuffs shall be brought into the barn only immediately before the feeding hour, which shall follow the milking. The food shall be suitable and well balanced. The cows must have at least two hours out of door exercise daily in suitable weather. The hands of the milkers shall be washed thoroughly and dried before beginning milking and before the milking of each cow. Clean outside clothes

and a cap shall be worn during milking, these to be washed or sterilized each day. The fore-milk shall be rejected. The milk of all cows shall be excluded for a period of forty-five days before and seven days after parturition. The milk shall be taken immediately to a clean room and emptied through strainers of cheesecloth or absorbent cotton into a can.

The dairy building shall be located at a suitable distance from the stable and dwelling and there shall be no hogpen, privy or manure pile at a higher level or within 300 feet of it. The dairy building shall be kept clean and shall not be used for purposes other than the handling and storing of milk and milk utensils. It shall be well lighted, screened and drained.

The temperature of the milk shall be immediately reduced to 45° F. and maintained at a temperature between 35° F. and 45° F. until delivery to the consumer. The bottles shall be properly sealed, the seal to include a sterile hood which completely covers the lip of the bottle. The bottles shall be properly cleaned and sterilized. The milk pails shall be properly made and preferably have an elliptical opening 5 by 7 inches in diameter. The water supply shall be free from contamination. Proper toilet facilities shall be provided for the milkers outside the stable and milk house.

The milk packages must be kept free from dust and dirt during transportation. No bottles shall be collected from houses in which there is a communicable disease. All certified milk shall reach the consumer within thirty hours after milking.

The herd shall be free from tuberculosis, as shown by the proper application of the tuberculin test by the veterinarian of the commission. The test shall be applied at least annually. All cows shall be properly registered. Cows sick with other diseases than tuberculosis shall be isolated and their milk destroyed until the cows are restored to the herd by the veterinarian.

Certified milk shall contain less than 10,000 bacteria per cubic centimeter when delivered. Bacterial counts shall be made at least once a week.

The fat standard for certified milk shall be 4%, with a permissible range of variation of from 3.5% to 4.5%. Higher fat percentages for milk or cream may, however, be certified. The fat content shall be determined at least once a month.

The protein standard shall be 3.50%, with a permissible range of variation of from 3% to 4%. The milk shall be free from adulteration and coloring matter and preservatives shall not be added thereto. The milk shall not be subjected to heat unless especially directed by the commission to meet emergencies. The specific

gravity shall range from 1.029 to 1.034. It shall be determined at least once a month.

No person shall be employed in the production or handling of milk until he has been found healthy by the attending physician. No person shall be employed who has been recently associated with children sick with contagious diseases. Suitable dormitories and bathing facilities shall be provided for the employees and they shall be required to use them. If a contagious disease develops among the employees, the employees shall be quarantined, the premises fumigated and the milk pasteurized as long as the commission thinks necessary. The commission shall have power to act as its judgment dictates when contagious diseases are present.

It is possible to produce a reasonably clean milk without fulfilling all the requirements of the American Association of Medical Milk Commissions for the production of certified milk. It is possible to do this, moreover, without increasing materially the cost of the production of the milk. The milkers and those who handle the milk must, of course, be clean. So also must be the utensils which are used. The barns can easily be so arranged as to be reasonably free from dust and dirt. Experience has shown that the contamination of the milk is much less when the cows are milked out of doors than when they are milked indoors. If the cows are milked indoors certain precautions should be taken to avoid filling the air with dust. No dry feed should be given at or just before the time of the milking and the floors should not be scraped or cleaned just before milking. The cows should not be dry brushed before milking. The flanks and udders may be wiped instead of washed before the milking. This is nearly as effectual and much less expensive. A covered milk pail should always be used as it diminishes the contamination at least 50%.

CHAPTER XVII

GENERAL PRINCIPLES OF ARTIFICIAL FEEDING

In approaching the subject of artificial feeding it must be remembered that there are only a few food elements. A baby's food may contain all of these elements, it must contain some of them, it cannot contain any other elements. These food elements are fat, carbohydrates, protein and salts. The carbohydrates comprise the sugars and starches.

It must also be remembered that a baby, in order to thrive and gain, must have a sufficient amount of food. The amount of food is not calculated, however, in ounces or pints of food, but in food values, or calories. A baby must receive a sufficient number of calories in proportion to its body weight. Otherwise, it cannot gain. It is not sufficient, however, for a food to contain a sufficient number of calories; it must also contain a sufficient amount of protein to cover the nitrogenous needs of the baby. A baby will eventually die while taking a food high in calories but too low in protein.

It must further be remembered that a food may contain a sufficient number of calories and a sufficient amount of protein to cover the caloric and protein needs of the baby and yet not be a suitable food for any baby, or, if suitable for one baby, not for another. It is absolutely necessary to fit the food to the digestive capacity of the individual infant. Otherwise it will cause disturbance of the digestion and the baby will not thrive.

These fundamental principles must always be borne in mind in feeding babies artificially. If a single one of them is forgotten, the results will be failure rather than success.

It would seem at first glance as if an artificial food, which contained the same food elements in the same relative proportions that they are in human milk, would be a perfect food and answer as well as human milk. It has been shown, however, that, while some babies will thrive on a food of this composition, it is not suitable for all babies or for all ages. While babies thrive throughout the nursing period on human milk of uniform strength, they cannot take a food as strong as this in the early weeks and months, and need a stronger food in the latter months. It is a fact, more-

over, that no artificial food, although it may contain the same proportions of the different food elements, is the same as human milk. It is impossible, as will be shown later, to make an artificial food in any way which is identical with human milk.

The composition of human milk does, however, teach us certain things as to the digestive capacity of infants and as to the general principles to be followed in the preparation of a food to meet this digestive capacity. Nature provides a dilute food rich in fat and carbohydrates and relatively low in protein, that is, rich in heat-producing substances and relatively low in tissue building substances. It seems reasonable to suppose that this type of food is the one best suited for the infant's digestive power and metabolic processes. Well babies should, therefore, be given dilute foods which contain relatively large amounts of fat and carbohydrates and relatively small amounts of protein. The object in giving babies such foods is, however, not to imitate the composition of breast-milk but to follow Nature's indications as to the infant's digestive capacity and metabolic processes. Well babies, as already stated, on the whole thrive better on foods of this character than on any others. The same principles cannot, however, be applied to the feeding of sick babies or to that of a certain number of well babies. When a baby does not thrive on foods of this type, they must be discarded at once and the composition of the food regulated to fit the digestive capacity of the individual baby. This digestive capacity must be determined by a careful study of the symptoms and of the stools in the individual case. The composition of the food must then be varied to suit the individual baby. Success in the artificial feeding of infants can never be attained by following any hard and fast rules. Every baby is a problem by itself. The baby, not rules, must be followed to solve this problem.

The artificial food for a baby is best prepared from the milk of some animal for the following reasons: The milk of animals contains the same food elements which are present in human milk. It does not contain any other elements. It is intended for the growth and development of a young animal. No other food has these same characteristics. It must be remembered, however, that the milk of an animal is fitted to the digestive capacity and intended for the growth and development of the young of that animal and not for the human infant. It is, therefore, not entirely suitable for a baby, and, while some babies will thrive on the undiluted milk of an animal, in most instances it has to be modified in some way to be suitable for a baby.

The milk of the cow is the one most suitable for the preparation of a baby's food. The milk of the mare, it is true, resembles more closely in its composition that of human milk than does cow's milk. Its use as a food for babies is, however, not feasible, because of its rarity and the difficulty in obtaining it. The milk of the goat, which is claimed by some authorities to be better than cow's milk as a food for babies, resembles in its composition that of human milk a little more than does cow's milk. The difference is so slight, however, that goat's milk has to be modified to fit the digestion of the average baby in the same way as cow's milk. Cow's milk is easy to obtain in any amount, in almost any place. It is difficult to obtain goat's milk in large amounts, and then only in a few places. There is, therefore, no reason for preferring goat's milk to cow's milk. The reasons that goat's milk has been considered better than cow's milk for the feeding of infants are probably because goat's milk was given to the babies when it was fresh and cow's milk when it was old, and because in the countries where goat's milk was used most freely the cows were tubercular and the goats, on account of their resistance to infection with tuberculosis, were not. At the present time when so much is known about infant feeding, these reasons are not applicable. Pure milk can now be obtained by anyone who will take the trouble to get it, and anyone who does not take the trouble to find out whether the milk which is given to a baby comes from tuberculin tested cows or not, deserves to have tuberculosis develop in the babies.

Idiosyncrasy to Cow's Milk.—It is often said that certain babies cannot take cow's milk in any form and that they must be fed, therefore, in some other way. In most of these cases the trouble is not with cow's milk but with the way in which it has been given. Almost all of these babies can take cow's milk perfectly well if it is properly modified to fit their individual digestive capacities. In rare instances, however, cow's milk does cause serious disturbances in whatever form it is given, whether as cream, skimmed milk, whey or condensed milk. In such cases even a very small amount will cause trouble. In these instances the symptoms are probably manifestations of anaphylaxis to the protein of cow's milk. It will almost always be found that these babies were given cow's milk in the first few days of life at a time when the intestines were in an abnormal condition. The foreign protein of the cow's milk was probably absorbed at that time and produced the sensitization. Such babies have to be given either breast-milk or goat's milk until they are old enough to take other

foods than milk. The idiosyncrasy is usually outgrown during early childhood.

Modified Milk.—The composition of human milk and cow's milk has already been given. They are roughly as follows:

TABLE 38

	Human milk	*Cow's milk*
Fat	4.00%	4.00%
Sugar	7.00%	4.75%
Protein	1.50%	3.50%
Salts	0.20%	0.70%

Both are amphoteric in reaction when they leave the breast. Cow's milk is usually acid when it reaches the baby. Human milk is practically sterile as the baby takes it. Cow's milk, even under the best conditions, is far from sterile when the baby gets it. The emulsion of the fat is much finer in human milk than in cow's milk. The proportion of fatty acids is much higher in cow's milk than in human milk. A large proportion of the protein in human milk is in the form of whey protein. A large proportion of the protein in cow's milk is in the form of casein. Human milk is not coagulated by commercial rennin, cow's milk is coagulated. Both are coagulated by human rennin. The enzymes of the two milks are different and each milk has a specific serum reaction.

It is evident, therefore, that no matter how cow's milk is modified, it will still be different from human milk. The percentages of the different food elements can be made the same. The difference in the protein can be corrected by the use of whey. The emulsion and the composition of the fat will, however, always be different. The ferments can never be made the same and the specific serum reaction cannot be changed. It is also evident that cow's milk must be modified in some way in order that the different food elements may be in the same relations in the food that they are in human milk.

Pure Milk.—The milk from which a baby's food is prepared must be pure. It is impossible to make a proper food for a baby from impure and dirty milk, no matter how much it is modified or how much care is taken in its preparation. The requisites of a pure milk have already been described.

Breeds of Cows.—It also makes a difference from what breed of cows the milk comes. The milk of Ayreshires and Holsteins is much more suitable than that of Jerseys and Guernseys, because of the lesser fat content, the finer division of the fat and the lower

proportion of volatile fatty acids. The milk of the former breeds should, therefore, be always employed, if possible. Some babies can take Jersey milk without being disturbed, other babies cannot. It will be found in many instances that babies can take the same amount of fat in mixtures made from the milk of Holstein and Ayreshire cows without derangement of digestion while there is serious disturbance when the milk comes from Jerseys or Guernseys.

Mixed Milk versus the Milk of One Cow.—It is far better, other things being equal, to use the mixed milk of a herd in preparing a baby's food than the milk of one cow, because if the milk comes from one cow and the cow is ill in any way, the baby is almost certain to be disturbed, whereas if one or two cows in a herd are ill, the milk from these cows will be so diluted that the baby will probably not notice it. On the other hand, it is, or should be, self-evident that the milk of a healthy cow properly fed and properly cared for, taken in the proper way, and kept under proper conditions, is better than the mixed milk of a herd which is improperly fed and whose milk is not carefully obtained or carefully taken care of.

GENERAL PRINCIPLES OF THE MODIFICATION OF MILK

It is evident, when the composition of human milk and cow's milk is compared, that, while the percentage of fat is the same in the two milks, the percentage of sugar is higher and that of the protein lower in human than in cow's milk. It is necessary, in order to have foods prepared from cow's milk correspond in the general relations of the fat, sugar and protein to each other to those in human milk and, therefore, to meet the indications for a food suitable for the average well baby, to modify these relations in some way. Simple dilution of cow's milk does not change these relations at all. Simple dilutions of whole milk do not, therefore, provide a suitable food for the average well baby.

It is a fact that when milk stands the fat rises to the top, while the sugar and protein remain approximately evenly divided throughout the mixture. This fact of the unequal division of the fat and the comparatively equal division of the sugar and protein is also true when milk is separated by machinery. The cream contains a relatively large amount of fat and a relatively small amount of sugar and protein, when compared with whole milk.

Cream is technically any milk which contains more than 4% of fat. The composition of different creams is as follows:

TABLE 39

	Fat	*Sugar*	*Protein*
10% cream.........	10%	4.45%	3.27%
16% "	16%	4.20%	3.05%
32% "	32%	3.40%	2.50%

It is evident that when cream is diluted the relation between the fat and the protein will be similar to that in human milk. For example, a mixture of one part of 16% cream with three parts of water will contain 4% of fat and about 0.75% of protein, while a mixture of one part of 10% cream with three parts of water will contain 2.50% of fat and approximately 0.80% of protein. It is very easy to raise the percentage of sugar, in order to get a relatively high sugar content, by the addition of dry milk sugar. The modification of cow's milk to fulfill the indications given by Nature as to the average infant's digestive capacity consists roughly, therefore, in the dilution of cream with water and the addition of dry milk sugar.

If the modifications of milk prepared on these general principles do not fit the individual baby, it is easy to increase the percentage of protein in relation to the percentage of fat by the addition of skimmed or fat-free milk, which contain a considerable amount of protein and very little fat. If the casein is not easily digested, it is easy by the use of whey in the mixture to replace a part of it by whey protein. If it is desired to give a baby starch in its food, starch can be added in the form of a cereal water. If it is desired, for any reason, to change the character of the sugar, another sugar may be added in place of milk sugar. In these ways all possible modifications of cow's milk may be obtained and the needs of the individual baby met.

FEEDING IN PERCENTAGES

The most satisfactory way of determining the composition of an infant's food is by thinking and calculating in percentages of the different elements of the food. Percentage feeding, so-called, is not a method of feeding. It is merely a method of calculation and a means of attaining relative accuracy in the preparation of infants' foods. It neither presupposes nor implies anything as to what should be in the food or why it should be there. These points must be determined in other ways. Accuracy is as important in the calculation and writing of a prescription for a baby's food as in that

for a medicine. In no other way are such accurate results obtained as by the percentage method. It must not be supposed, however, that the mixtures, when prepared, contain exactly the percentages of the food elements which they are calculated to contain. This would be an impossibility, because the cream, milk and so on of which they are made are not constant in their composition. This is especially true when the mixtures are prepared at home. The percentages are, however, approximately correct and nearly enough so for practical purposes. Fortunately most babies do not notice slight variations in the composition of the food. In fact, the variations in the composition of a mixture from day to day are probably less than the daily variations in the composition of a breast-milk. In any event, the relative proportions of the various food elements are correct, even if the exact percentages are not. If the food does not agree, changes in the percentages to meet the indications furnished by the symptoms will be accurate relatively to the original percentages, which is all that is necessary.

USE OF CALORIES IN INFANT FEEDING

The calorie referred to in infant feeding is the large calorie, that is, the amount of heat necessary to raise one kilogram of water 1° C. A baby cannot thrive and gain unless its food contains a sufficient number of calories in a form which can be utilized by the baby. In general, babies require from 100 to 120 calories per kilogram of body weight during the first six months in order to gain, and in the neighborhood of 100 calories during the rest of the first year. Ninety calories per kilogram is usually sufficient during the second year. Most young babies will just about hold their weight on 70 calories per kilogram, a few will gain regularly on this amount while other babies need as much as 140 calories per kilogram in order to gain. Babies that have been underfed or that are convalescing from a severe illness, whether acute or chronic, need more calories than do normal babies. Babies that are fatter than the average baby will gain on fewer calories than will the average baby. The fatter the baby is, the fewer calories he needs, a very fat baby often needing only 90 calories per kilogram. Conversely, the thinner or more atrophic a baby is, the more calories it needs, many extremely emaciated babies requiring as much as 160 calories per kilogram. Another factor which modifies the caloric need of an infant is its muscular activity. The quieter a baby is, the less food it requires, and vice versa. That is to say, there is no hard and fast rule as to how many calories a given baby must have in

order to gain. The calculation of the caloric value of the food will show whether the failure to gain is due to an insufficient amount of food or to some other cause. On the other hand, if a baby has a disturbance of the digestion on a food which seems suitable for it, the calculation of the caloric value of the food will show whether the disturbance is due to overfeeding or not. It must be remembered, however, that while the caloric value of a food may be high, the food may be valueless to the baby, because it cannot utilize it. Cheese and crackers both have a high caloric value, but they are not suitable articles of diet for a three months' old baby. A food the caloric value of which is high and the composition of which is suitable for the average baby may in like manner be of but little value in a given case. For example, if a baby with an intolerance for fat is given a food whose caloric value is correct but which is due in considerable part to its fat content, it will not only not gain on this food but will be made ill. On the other hand, if the caloric value is due to the presence of sugar and protein, it would be able to utilize them and gain. Chapin has recently shown, moreover, that on account of the different powers of fat and carbohydrates as producers of metabolic water, they cannot be considered as interchangeable as regards favoring the growth of the organism. He has also called attention to the fact that the net caloric value of a food depends on the amount of energy required for its digestion and assimilation. Foods having the same gross caloric value may differ very materially, therefore, in their net caloric value.[1] It has also been shown many times that the caloric needs of an individual, whether baby or adult, depend very largely on the amount of exertion which the individual makes, the need of food for the production of energy depending on exertion. It is evident, therefore, that a quiet baby which sleeps all day requires much less food energy than an active, restless baby, or one which cries most of the day.

It is evidently irrational, therefore, to base any scheme or system of feeding on the caloric needs of babies or on the caloric values of food. The calculation of the calories in a given food can serve merely as a check. Used in this way it is often of great value.

Intervals in Artificial Feeding.—While, as already stated, babies that are nursed do much better on the whole when they are fed at regular intervals, many of them get along fairly satisfac-

[1] Chapin: New York Medical Journal, 1913, xcvii, 269.

torily and some of them thrive perfectly well, even if fed at any and all times. This is not the case with artificially-fed babies. They are almost certain to be upset and suffer from disturbances of digestion, unless they are fed at regular intervals. Regularity is not only advisable with them, as with the breast-fed baby, but necessary. In general, the intervals are the same for the artificially fed as for the breast-fed. It is impossible and irrational, however, to lay down any arbitrary rules as to the intervals between feedings at different ages. They must vary with the amount of food given at a feeding, the strength of the food and its composition, as well as with the digestive capacity and gastric motility of the individual infant. It is evident that if a large amount is given at a feeding, the intervals between feedings must be longer than when a small amount is given, as the time required for the stomach to empty itself will be longer. The time required for the stomach to pass on a food rich in fat is greater than that required to pass on one poor in fat, because fat delays the emptying of the stomach. A mixture in which the protein is largely in the form of whey protein will leave the stomach more quickly than one in which the protein is almost entirely casein. Foods rich in carbohydrates and low in fat and protein leave the stomach quickly. There is no doubt that the digestive capacity and gastric motility is different in different infants. It is evident, therefore, that the intervals must be determined in each case on the conditions actually present in that case, not by any set rules.

Amount of Food at Single Feeding.—When a baby is nursed, Nature, under normal conditions, regulates the supply to the demand and there is no danger of overfeeding. There is no such natural relation, however, between what the person in charge of a baby may think it requires and its actual needs. A breast-fed baby, while it will take practically the same amount of milk from day to day, does not take the same amount at each feeding. It will, in fact, often take three or four times as much at one feeding as it does at the next without suffering any disturbance of the digestion. It has been found, however, that it is not safe to let a baby take all that he will at each feeding from an unlimited supply of artificial food. If this method is followed, indigestion almost invariably results. In order to avoid trouble, the baby must be given the same amount at each feeding. This amount is the maximum which is proper for the given baby. It is not necessary, however, that the baby always takes the whole of it.

It is very difficult, indeed, to know just how much food a baby should take at a feeding. It depends not only on the age, but

also upon the size of the individual baby. Some babies, moreover, require more food than other babies of the same age and weight. The amount of food given at a feeding must depend also on the intervals between feedings. It is self-evident that, the twenty-four hour amount being the same, more food must be given at a feeding when the intervals are long than when they are short. The amount of food to be given in 24 hours is the most important point to be determined. When this is decided, it must be divided equally according to the number of feedings to be given. If the twenty-four hour amount is correct, the amount given at a feeding and the number of feedings are, within reasonable limits, relatively unimportant. The figures as to the gastric capacity at different ages are of comparatively little value because of the difficulties and inaccuracies inherent to the various methods of determining them. Even if these figures were correct, they would not be of great value, because of the fact that more or less of the food ingested passes from the stomach into the duodenum while it is being taken. How much passes varies undoubtedly in different babies and in the same baby at different times.

Experience has shown that the amount of food taken in twenty-four hours increases rapidly during the first three months and less rapidly during the remainder of the first year. The average baby takes ten or twelve ounces at the end of the first week, twenty ounces when a month old and thirty-two ounces when four months old. It will take thirty-six to forty ounces at six months and forty-eight ounces at nine months.

It is evidently impossible, therefore, to give any absolute figures as to how much food should be given a baby of a certain age. In a general way, however, the average baby takes about one-half ounce at a feeding in the first few days, and an ounce to an ounce and a half when it is a week or ten days old. It takes about two and one-half ounces when it is a month old, four ounces at three months, six ounces at six months and eight ounces at nine months. It is, as already stated, impossible to lay down any hard and fast rules as to the intervals between feedings and the amount to be given at a single feeding at given ages. The intervals and the amount at each feeding must vary with the circumstances in the individual case. While this is true, it is, nevertheless, possible to give certain figures, founded on what average babies have been found by experience to have done in the past, as to what the average baby may be expected to do. These figures must not be followed blindly, but can serve as a guide as to what may be expected of an average baby of a given age.

TABLE 40

Age	*24-hour amount*	*Number of feedings, amount and intervals*
1 week	10–12 oz.	10 feedings of 1 oz. at 2 hr. intervals 8 " 1½ oz. 2½ hr. "
4 weeks	20 oz.	8 " 2½ oz. 2½ hr. " 7 " 3 oz. 3 hr. "
4 mos.	32 oz.	7 " 4½ oz. 3 hr. "
6 mos.	36–40 oz.	6 " 6 or 6½ oz. 3 hr. "
9 mos.	48 oz.	6 " 8 oz. 3 hr. " 5 " 9½ oz. 3 or 4 hr. "

Ten feedings at two-hour intervals means every two hours from 6 A. M. to 10 P. M. and once between ten and six at night.

Eight feedings at two and one-half hour intervals means every two and one-half hours from 6 A. M. to 9 P. M. or 10 P. M., and once between the evening feeding and morning.

Seven feedings at three-hour intervals means every three hours from 6 A. M. to 9 P. M. or 10 P. M., and once between ten and six at night.

Six feedings at three-hour intervals means every three hours from 6 A. M. to 9 or 10 P. M.

Five feedings at three-hour intervals means every three hours from 6 A. M. to 9 P. M.

Five feedings at four-hour intervals means every four hours from 6 A. M. to 10 P. M.

The night feeding may be omitted, in many instances, before the baby is six months old. If so, the amount which was in this bottle must be distributed among the other bottles in order to keep the twenty-four hour amount the same.

Composition of Food at Different Ages.—It is impossible to over-emphasize the facts that babies cannot be fed by rule and that the food of each baby must be adapted to the digestive capacity of that individual baby. It is equally true, however, that young infants cannot take as strong an artificial food as older babies and that the average well baby thrives better on artificial foods in which the relation of the fat, sugar and protein in the mixture are similar to those in human milk. Experience in the feeding of large numbers of well babies has shown that, on the average, babies of certain ages take, digest and thrive best on certain strengths of food. The expert in the feeding of infants has

no need of tables showing the average strength of food taken at different ages. He is able to judge very closely from the age, appearance and past history of the baby what food is suitable for it. Those of less experience, however, need such a table to serve as a guide in the preparation of the first mixture for a well baby when it comes into their hands, and to show them in a general way what the average well baby may be expected to take. In any hands, the first formula must always be something of an experiment. After this, the food must be prepared to meet the indications furnished by the symptoms, the findings in the stools, the appearance and the weight chart of the individual baby at the given time.

TABLE 41

Composition of Food for Average Well Babies

Age	*Fat*	*Sugar*	*Protein*
First food	1.00	5.00	0.50
First week	2.00	6.00	0.75
1 month	3.00	7.00	1.00
2 months	3.50	7.00	1.50
4 months	4.00	7.00	1.75
6 months	4.00	7.00	2.25
8 months	4.00	7.00	2.50

Variation of Different Food Elements.—It is possible not only to vary the percentages of the different elements in the food, but also to use these elements in different forms. There are, for example, several varieties of sugar, one of which will agree in one condition, another in another. Barley starch may be used in one instance, oat starch in another. Whey protein may be given instead of casein when the latter causes disturbance, or the casein may be partially digested by pancreatization. Alkalies may be added to the food or lactic acid organisms may be grown in it, and so on.

Fat.—The amount of fat in the food may be varied, but the character of the fat cannot be changed, except in so far as it differs in the milk of different breeds of cows. The emulsion of the fat may be made much more complete, however, by means of the process known as "homogenization," by which the fat droplets are rendered extremely small. Other fats, such as olive oil, may also be introduced into the milk by this process. It has been thought by some physicians that the cream obtained by centrifugalization is less suitable for the preparation of foods for infants

than that obtained by gravity. There is, however, no proof that this is so, and the general experience is that it makes no difference whether the cream is obtained by gravity or centrifugalization. The upper layers of cream which has risen contain many more bacteria than the lower. It is of certain advantage, therefore, to remove the upper two ounces of cream from each quart in order to reduce the bacterial contamination.[1]

Very few babies are able to take more than 4% of fat in their food continuously without developing disturbances of digestion or of nutrition. More than 4% of fat should, therefore, never be given, except for special indications, and, if it is so given, it should not be kept up for any length of time. Most well babies over three months old can take 4% of fat without any trouble resulting. Indeed, in most instances they thrive better on this amount than on lower percentages. This is not the case with sick babies, however, and here, as always, it must never be forgotten that conclusions as to what is a suitable food for a sick baby cannot be drawn from what is suitable for a well one. It is safer when babies are fed on modifications of milk prepared at home not to give more than 3 ½%, or even more than 3% of fat, because, as in most methods of calculation the fat content of the skimmed milk is disregarded, the foods always contain more fat than they are supposed to.

One of the reasons why too high percentages of fat are given is the desire to make the baby gain in weight. Mothers are always and physicians not infrequently inclined to attach too much importance to the weight chart and, believing that fat tends to increase the weight more than anything else, to increase it unduly on this account. As a matter of fact, the fat baby is often not as strong and vigorous as the thinner baby, and fat in the food is no more useful than carbohydrates in increasing weight.

Another reason why babies are given excessive amounts of fat is that most mothers and nurses, and unfortunately many physicians, think that fat always has a laxative action. They, therefore, increase the amount of fat in the food whenever a baby is constipated, not realizing that an excessive amount of fat is one of the most common causes of constipation in infancy. Increasing the percentage of fat in the food in such cases, of course, merely makes a bad matter worse.

The chief reason why babies get excessive amounts of fat in their food is that physicians do not appreciate the fact that cream and top milk are indefinite terms or that, if they do appreciate this fact

[1] Hess: Journal A. M. A. 1909, liii, 523.

and are careful in their calculations, they are not precise enough in their directions as to the preparation of the food. If 32% cream is used in the preparation of a milk mixture, the formula for which was calculated on the basis of 16% cream, it is evident that the mixture will contain twice as much fat as was intended. In the same way, if a top milk mixture is made with a certain number of ounces from the top eight ounces instead of with the same number of ounces from the top sixteen ounces as ordered, it will contain nearly twice as much fat as it should, the fat content of the top eight ounces being 13.3% and that of the top sixteen ounces, 7%. The physician must always decide what percentage cream or what top milk he will use in the preparation of his mixture, and then calculate the amount to be used on the basis of its fat content. Otherwise, the fat content of the food will never be what he thinks it is. He must also give the person who is to prepare the food such explicit directions as to how to obtain the cream or top milk that they cannot possibly make a mistake.

It must be remembered on the other hand, however, that the caloric value of fat is more than twice as great as that of the carbohydrates and protein. Unless a reasonable amount of fat is used in the food, it is, therefore, often difficult to meet the caloric needs without unduly increasing the quantity of the food.

Sugars.—Milk sugar being the only form of sugar present in human milk and in the milk of animals, it seems reasonable to suppose that it is the sugar most suitable for the growth of the young organism, whether human or animal. It is hardly necessary, however, to adduce this argument in favor of milk sugar, because there are several reasons which show that it is the most suitable form of sugar for well infants. It is more slowly but more completely absorbed than the other disaccharides. Being more slowly absorbed, it is present for a longer time and at lower levels of the intestines than the others, and is thus more conducive to the development and persistence of the normal fermentative flora throughout the intestinal tract. Few organisms, moreover, other than those normal to the intestinal tract of infants, utilize lactose before it is broken down, while many can utilize the other double sugars. It affords, therefore, a more efficient protection against abnormal bacterial processes in the intestine.

It is probably true that the net energy value of milk sugar is less than that of malt sugar, because of the greater energy presumably required for its utilization. It does not seem probable, however, that this difference is sufficient to be of practical importance. It has been suggested that on account of the differences in the salts of

human and cow's milk, the sugar in the two milks may not be utilized in the same way. There is, however, no proof of the correctness of this suggestion. It has also been claimed that the lactose of cow's milk is not identical with that of human milk. There is, however, no convincing evidence in favor of this claim. No difference having thus far been found in the chemical composition of lactose from different sources, it seems more reasonable, therefore, to consider them identical until they are proved not to be. It must be remembered, however, that commercial milk sugar is not always pure.

No more than 7% of milk sugar should be given in an infant's food. If for any reason a larger amount of sugar than this is required, the additional sugar should be given in the form of one of the combinations of dextrin and maltose. These sugars are quickly absorbed and the intestine is, therefore, not flooded with an excess of sugar for a long time, as it would be if milk sugar was used exclusively. Milk sugar is never found in the urine or feces under normal conditions, unless more than 7% of sugar is given. In fact, the assimilation limit of milk sugar, although lower than that of the other disaccharides, is far in excess of the amount which would be contained in any reasonable food.

Lactose in reasonable amounts under normal conditions has a slight laxative action, as does maltose, while saccharose is slightly constipating. When given in excess, lactose is more likely than the other disaccharides to cause diarrhea, the order being lactose, saccharose, maltose and dextrin-maltose mixtures. The probable explanation of the greater frequency with which lactose causes diarrhea is its relatively slow absorbability.

It is stated that lactose causes fever more readily than the other disaccharides, the order being lactose, saccharose and maltose. The fever is always accompanied by diarrhea, however, so that the presence of fever is no argument against the use of lactose in reasonable amounts under normal conditions. Schlutz's experiments render it very improbable, moreover, that, even when there is a rise in temperature, it is due primarily to the sugar. This so-called "sugar fever," provided there is such a thing, is, therefore, no argument against the reasonable use of milk sugar.

When the disaccharides are added to a food which contains little or no sugar, there is a rapid increase in weight owing to the lessened elimination of water by the kidneys as the result of the presence in the organism of the products of assimilation of the sugar absorbed. The difference in the increase of weight with different sugars is due to the difference in the quantity of liquid eliminated by the

kidneys. The gain in weight is more rapid with maltose and saccharose than with lactose, probably because of the easier assimilation and more rapid absorption of these sugars.[1] This fact is the probable explanation of the sudden increase in weight which not infrequently follows the change from a modified milk prepared with milk sugar to one of the proprietary foods containing some compound of the dextrins and maltose.

There can be no doubt, therefore, that under normal conditions the preferable sugar for the well infant is lactose. This is not the case, however, in many of the disturbances of digestion. Some of these are due to an excessive amount of milk sugar in the food. They can be quickly relieved by a reduction in the percentage of milk sugar. In others, while the disturbance is not due primarily to the amount of milk sugar, the chief cause of the symptoms is the fermentation of the milk sugar as the result of abnormal bacterial activity. In such instances the milk sugar must be stopped and some other form of sugar substituted for it.

Maltose.—Pure maltose is never employed in the feeding of infants, being altogether too expensive to be used in this way. The various preparations to which this term is erroneously applied are mixtures of the various dextrins and maltose. The relative proportions of the dextrins and maltose are different in all of them. The relations of the various dextrins to each other are also different. The composition of a few of these preparations is as follows:

TABLE 42

Food	*Maltose per cent.*	*Dextrin per cent.*
Soxhlet's Nährzucker	52.44	41.26
Löflund's Nährmaltose	40.00	60.00
Mead's Dextri-Maltose	51.00	47.00
Neutral Maltose (Maltzyme Co.)	63.00–66.00	8.00–9.00
Löflund's Malt-Soup Extract	58.91	15.42
Maltose (Walker-Gordon Laboratory)	57.10	30.90
Mellin's Food	58.88	20.69
Malted Milk	49.15 [2]	18.80

The properties of maltose and the dextrins are materially different. Maltose is a disaccharide, dextrins are polysaccharides. Maltose is a crystalloid, fermentable and dialyzable; the dextrins are reversible, protective colloids, non-fermentable and non-dialyzable. It is evident, then, that it is not a matter of little

[1] Borrino: Abstract in Archives of Pediatrics, 1911, xxviii, 869.
[2] A small proportion of the sugar is lactose.

importance which of these preparations is used. All are, of course, eventually absorbed in the form of dextrose. The dextrins, being protective colloids, in all probability have a favorable influence on the digestibility of the protein in the same way as does starch. Maltose has no such action. The dextrins have to be changed to maltose and then to dextrose before they are absorbed. The larger the proportion of dextrin in the dextrin-maltose mixtures, the slower, therefore, is the absorption of sugar and vice versa. There is, consequently, less danger of overtaxing the absorptive mechanism of the intestine and of flooding the organism with sugar when the proportion of the dextrins is relatively high. On the other hand, if it is desired to give the sugar in a form which can be very readily and rapidly absorbed, the proportion of maltose should be large. The preparations containing relatively large amounts of maltose are more laxative than those containing relatively large amounts of the dextrins, because of the larger amount of sugar which is present at one time in the intestine.

When the dextrin-maltose preparations are prepared in the home by the action of enzymes on starch solutions the character of the product may be varied to a certain extent. Temperatures below 131° F. (55° C.) produce the largest amount of maltose, and above 145° F. (63° C.) produce the dextrins in excess. A temperature of 167° F. (75° C.), however, stops the action of the enyzmes. Pure maltose is never produced, because after the concentration of the maltose reaches a certain point, the further production of dextrin, and therefore of maltose, is inhibited.

Maltose is split into dextrose and dextrose which can be immediately utilized. Lactose is split into dextrose and galactose, and saccharose into dextrose and levulose. Only the dextrose half of these sugars is, therefore, immediately available without further change. This immediate availability of the whole of the malt sugar is presumably of some advantage in feeble, emaciated babies, who have little or no reserve of glycogen in the liver, in that all the energy derived from the sugar may be used immediately in the digestion of the rest of the food, whereas the energy of the other sugars is not at once utilizable, the galactose and levulose halves having to be converted into glycogen in the liver and then reconverted into maltose and dextrose. The net energy value of malt sugar is also presumably somewhat greater than that of lactose and saccharose, because the sugar being converted at once into dextrose, no further energy is required, as there is to convert the galactose and levulose. The immediate utilizability of malt sugar is the chief point in favor of the employment of this form of sugar in the

feeding of babies not suffering from disturbances of the digestion. This fact, while of importance in the feeding of feeble and emaciated babies who have but little or no reserve of glycogen in the liver, is of no advantage in the feeding of normal infants. In fact, it is probably somewhat of a disadvantage. Milk sugar, which is more slowly broken up and more slowly stored in the liver in the form of glycogen, is more suitable, in that it is less likely to overtax the liver and cause alimentary glycosuria and excessive fat production.

Maltose, being more quickly absorbed, is less favorable to the maintenance of the normal fecal flora than lactose. Maltose, moreover, is especially conducive to the growth of the bacillus acidophilus, which, although normally present in small numbers, if present in large numbers is liable to produce an excessive degree of acidity, and this may cause irritation of the intestine and an intolerance for sugar. Under normal conditions, therefore, as far as the maintenance of the normal intestinal flora is concerned, lactose is preferable to maltose.

There is a form of indigestion, chiefly intestinal, in infancy due to the fermentation of milk sugar. In the convalescent stage of this condition the dextrin-maltose preparations can be given sooner than lactose without causing a return of the symptoms. Their use is, therefore, indicated in this condition. The preparations containing a relatively large proportion of dextrins are preferable, because they are broken down more slowly. Sugars are contraindicated in diseases of the intestinal tract due to the gas bacillus and similar organisms. Maltose is more harmful than lactose because it undergoes butyric acid fermentation more readily. Maltose is less suitable than lactose for the feeding of infants ill with diseases due to the bacteria which produce toxic substances from protein, and non-toxic substances from carbohydrates for several reasons. Lactose is more slowly broken down and absorbed and consequently exerts a more prolonged action. In the next place, few organisms except those normal to the intestinal tract of infants can utilize it before it is broken down by hydrolysis. There is also danger, as already pointed out, if maltose is given freely, of encouraging the overdevelopment of the bacillus acidophilus and developing a sugar intolerance.

Cane Sugar.—There seems to be no evident reason for using cane sugar in place of milk sugar in feeding normal infants except that it is less expensive. It is true that many infants thrive on it. This fact, however, does not prove that it is preferable to milk sugar, because the average normal infant is able to utilize lactose,

saccharose or the dextrin-maltose mixtures indiscriminately, provided they are not given in excess. That is, normal babies that thrive on cane sugar do so in spite of it, not because of it. Cane sugar, undergoing as it does alcoholic fermentation instead of lactic acid fermentation, is less suitable for the development and maintenance of the normal intestinal flora than milk sugar. Granting that the experimental evidence that the assimilation limits of cane sugar are greater than those of milk sugar and that it is less likely to cause diarrhea and "sugar fever" than milk sugar is correct, which is certainly open to question, even then it is inferior in all these respects to the dextrin-maltose mixtures. Therefore, if there is any reason to believe that there is a disturbance of the digestion from the presence of milk sugar in the food, the dextrin-maltose mixtures should be substituted for the milk sugar, not cane sugar. The dextrin-maltose mixtures are also preferable to cane sugar in the feeding of feeble, emaciated infants to whom it is desirable to give a rapidly utilizable sugar because, like milk sugar, it is only half dextrose, the levulose being available only after further changes.

It is stated that, when used continuously, cane sugar has a slightly constipating action, while milk sugar and the dextrin-maltose mixtures are slightly laxative. This action is, however, hardly strong enough to be of any practical importance.

Starch.—It has been proved beyond question that amylolytic ferments are present in the saliva and pancreatic secretions of the new-born infant, even if it is born prematurely. These ferments are present and active in the breast-fed as well as in the artificially-fed infant. The amylase of the pancreatic secretion is more abundant after the first month than earlier. After the first month the activity of the pancreatic amylase seems to depend more on individual peculiarities than on the age of the baby. The amount of the secretion is apparently independent of the character of the food. It is not diminished in atrophic conditions. There are, therefore, no physiological contraindications to the use of starch in the feeding of infants, even of the new-born. This fact does not prove, however, that infants ought always to be given starch or that they should be fed on foods composed largely or almost exclusively of starch. It merely shows that there is no reason why starch should not be given to babies, if there is any good reason for using it. Clinical experience shows that, in general, it is not advisable to give starch to babies under two months old, although there are many exceptions to this general rule. Clinical experience also shows that it is inadvisable to give large amounts of starch to

babies before they are ten months old. It shows, on the other hand, however, that many babies do far better on foods containing starch than they do on foods which do not contain it. Starch should be used in the food of infants in the same way as the sugars, fat and protein, that is, intelligently and for definite purposes and indications. The percentage of starch in the food should be just as carefully calculated as that of any of the other elements.

The caloric value of starch is, for practical purposes, the same as that of sugar, the loss of nutritive value resulting from the greater energy expended in breaking down the starch being, for every-day work, negligible. The starch is, of course, ultimately converted into dextrose before it is utilized. Starch is used less frequently, however, primarily for its nutritive value than for its other properties.

Starch acts as a protective colloid and in this way prevents the formation of large casein curds. This action is due to the soluble starch itself, not to the salts or to cellulose in suspension. It has been found that percentages of starch greater than 0.75% in milk mixtures have no more effect in diminishing the size of the curds than does 0.75%, while smaller percentages have less effect. When starch is added simply for its effect on the coagulation of casein, 0.75% is, therefore, the optimum amount.[1] This amount of starch is very seldom outside of the limit of tolerance of even the youngest and feeblest infant.

Starch is very useful when it is desirable to give carbohydrates to infants in whom the sugars cause fermentation or in whom the tolerance for sugars is so low that they cannot be given in sufficient quantities to supply the caloric needs which cannot be met by fat and protein. The probable reason that babies can take carbohydrate in the form of starch, when they cannot take it in the form of dextrins and sugar, is that the molecular structure of starch is more complicated than that of the dextrins and sugars. The more complicated the structure of a carbohydrate is, the more numerous are the steps in its breaking down to its end products. There are, therefore, less fermentable materials in the intestine at one time and less opportunity is afforded for fermentation to get the upper hand.

Starch is used in infant feeding in the form of the cereal waters or gruels. The nutritive value of these waters and gruels rests almost entirely in the starch which they contain. The cereal waters contain about 1.50% of starch, 0.20% of protein and from 0.01% to 0.05% of fat. The gruels contain about twice as much of each

[1] White: Journal of Boston Society of Medical Sciences, 1900, v, 125.

element.[1] When it is remembered that these cereal preparations are used merely as diluents it is evident that the food value furnished by the fat in them is essentially nil, and that furnished by the protein negligible. Cereal diluents made from the whole grains contain more protein, however, than those made from the corresponding flours.

Starch is most commonly used in the form of barley or oat flour. Barley flour is usually considered to be somewhat constipating and oat flour to have a slightly laxative action. The action of these flours on the intestinal peristalsis is, however, not at all a constant one, barley starch having a laxative and oat starch a constipating action in some infants. Other forms of starch have been used but little in this country and it has been rather taken for granted that it makes but little difference what form of starch is used. This is probably true in most instances and when small amounts only are used. The investigations of Nagao [2] and Klotz,[3] show that barley and oat starch are broken down more rapidly by enzymes and bacteria than are wheat and rye starch. The former flours are more likely, therefore, to cause acidity and fermentation than the latter.

It must not be forgotten, however, that, while starch in reasonable amounts is often most useful in feeding infants, it may, if given in excessive amounts, cause very marked disturbances of digestion and of nutrition. The fermentation of starch results in the formation of free fatty acids, which exert a strong irritant action on the intestines and cause increased peristalsis. The injurious effect of these acids is the same, whether they are derived from carbohydrates or fat.[4]

On the other hand, an excessive amount of starch not infrequently causes constipation. The stools in such cases are hard, dry and light-brown, resembling the soap stool except in their color.

A baby on a purely carbohydrate diet or on one in which the carbohydrates are greatly in excess receives much less salts than it should, such a diet being poor in salts. The consequent disturbance in the retention of salts and water results in impairment of the nutrition and in marked diminution in the resistance to infection.[5] Serious disturbances of nutrition from the excessive use of starchy foods, although apparently common abroad, are fortunately comparatively rare in this country.

[1] Ladd: Archives of Pediatrics, 1908, xxv, 256.
[2] Zeitschr. f. experiment. Path. u. Therapie, 1911, ix, 227.
[3] Archiv. f. experiment. Path. u. Pharmacol., 1912, lxvii, 451.
[4] Stolte: Jahrb. f. Kinderheilkunde., 1911, lxxiv, 367.
[5] Salge: Jahrb. f. Kinderheilkunde., 1912, lxxvi, 125.

Polycarbohydrates.—Attention has recently been called to the use of "polycarbohydrates" in infant feeding. Those who use this term mean by it a combination of several carbohydrates in the same food. They believe that, on account of the difference in the rapidity of absorption of the different carbohydrates, more carbohydrate can be given in this way without overtaxing the power of the organism to assimilate and utilize sugar than when a single carbohydrate is used. This belief is unquestionably correct and there is no doubt that when there is a disturbance in the digestion of sugar it is of great advantage to give some of the carbohydrate in the form of starch. The rationale of the use of the dextrin-maltose mixtures and starch has already been considered in discussing these substances. Those who advocate the use of "polycarbohydrates" in infant feeding seem to forget, however, that mixtures of milk and cereal waters contain two carbohydrates, milk sugar and starch, and mixtures of milk, dextrin-maltose mixtures and cereal waters four carbohydrates, milk sugar, malt sugar, dextrins and starch. The principle is, therefore, not a new one. Owing to the inferiority of cane sugar to the other sugars as a food for infants and the comparatively slight difference in the fermentability of the various forms of starch, it hardly seems necessary to complicate the mixtures further by the addition of cane sugar and by the use of several varieties of starch in the same food. The mixtures of milk, dextrin-maltose mixtures and simple cereal waters contain the carbohydrates in sufficient variety to meet the indications for the "polycarbohydrates." The malt sugar is absorbed first, then the milk sugar, next the dextrins and finally the starch. The absorption is thus comparatively slow and continues for a long time. The sudden flooding of the organism with sugar is thus avoided.

Protein.—While the fats and carbohydrates can, with certain restrictions which have been considered elsewhere, be used interchangeably in feeding babies, neither can take the place of protein. The protein is essential to life, in that it is the only form of food which can replace the nitrogenous waste of the body and from which new cells can be built up. It is indispensable for the repair and growth of the body. New tissue cannot be formed from carbohydrates and fat. They serve as sources of energy. Protein can also serve as a source of energy and life can be sustained for considerable periods of time on a purely protein diet. Such a diet is, however, a wasteful one, throws an excessive amount of work on the organs of digestion and metabolism and seriously overtaxes the organs of elimination.

The protein need of the infant is much greater than that of the adult, in that it not only requires protein to replace tissue waste but also to build up new tissues. If the protein content of its food is below a certain level, it will eventually die of malnutrition, no matter how high the caloric value of the food. If the protein content is just high enough to cover the tissue waste and a little more, the baby will live, but it will not thrive properly. It may become fat, but it cannot form bone and muscle as it should. The cause of anemia, obscure disturbances of nutrition, delay in muscular development and various functional derangements of the nervous system in infancy is not infrequently a deficiency of protein in the food. The average protein need of infants is at least 1.5 grammes per kilogram, or 0.7 grammes per pound of body weight. In all probability, many babies require as much as 2 grammes per kilogram, or 0.9 grammes per pound of body weight. Unless a baby gets this amount of protein in its food, it cannot thrive. It can often take much more than this with advantage.

The most available and the most easily digestible form of protein for infants is the protein of milk. The protein of woman's milk is more digestible than that of cow's milk. A part of the protein may be given in the form of vegetable protein, but vegetable protein cannot permanently replace animal protein in the infant's food.

There is no doubt that the opinion held some years ago that the protein was the most indigestible portion of cow's milk for infants and that the disturbances of digestion occurring in infants fed on cow's milk were almost entirely due to the protein, was an erroneous one. It is probable, on the other hand, that at the present time the tendency is to minimize the possible power of protein to cause disturbances of digestion and metabolism and to attach too little importance to it. One cause for this tendency is presumably that the disturbances caused by the proteins are, like those caused by the salts, less easily recognizable than those caused by the carbohydrates and fats. It has recently been shown, for example, than an excessively high protein diet will cause fever.[1] The products of protein metabolism, when in excess, undoubtedly irritate the kidneys. Further undesirable results of an excessive amount of protein will, in all probability, be discovered as the subject is more carefully studied.

The relation of the casein to the whey protein in human milk is approximately as 1 is to 2, while the relation in cow's milk is as 3 to 1. While it is possible, and perhaps probable, that there are

[1] Holt and Levene: American Journal of Diseases of Children, 1912, iv, 265.

considerable chemical differences between the protein of human milk and that of cow's milk, this is not proven. Setting aside, however, the undoubtedly important but still problematical action of the salts of the two milks on the digestibility of the protein, in the light of our present knowledge, the chief cause of the difference in the digestibility of the protein of human milk and that of cow's milk lies in the greater proportion of casein in cow's milk. In the first place, the absolutely greater amount of casein in cow's milk favors the formation of large, tough, casein curds, while the relatively smaller proportion of the whey protein to casein diminishes its collodial action in the prevention of the coagulation of the casein.

It is the formation of large curds which renders the casein of cow's milk so much more difficult of digestion by the infant than that of human milk. If the formation of large casein curds in the stomach can be prevented, the casein of cow's milk is easily digested. Fortunately, the average normal infant can digest considerable amounts of cow's milk casein in the usual dilutions without anything being done to prevent the formation of large casein curds. It is of a certain disadvantage, moreover, to render the digestion of the casein too easy, because, if this is done, the development of the digestive powers is not encouraged as it should be.

Methods of Preventing the Formation of Casein Curds. *Reduction of the Amount of Casein.*—The simplest method of preventing the formation of casein curds is by diminishing the amount of the casein and thus giving it more diluted. In using this method, however, great care must be exercised not to reduce the casein so much that the protein need is not covered. Some other method is, therefore, usually preferable.

Whey Mixtures.—One of the best methods of giving the protein in an easily digestible form is the whey mixture. The whey protein is not coagulable by rennin and, therefore, cannot form curds. Moreover, by its colloidal action it hinders the formation of large, casein curds. The presence of the protein in the whey makes it possible to diminish the casein materially without incurring the danger of protein starvation which is always present when the casein is reduced by simple dilution. The whey mixture is less valuable when the food is prepared at home than when it is prepared at a milk laboratory, because, when gravity cream is used, as it has to be in the home, the amount of cream which has to be used in order to have sufficient fat in the mixture carries with it a considerable percentage of casein and consequently reduces the amount of protein which can be given in the whey. When whey

mixtures are prepared at a milk laboratory, however, where high percentage creams can be used, the casein can be made very low and the whey protein high.

Whey mixtures are also very useful when there is much vomiting, the whey protein, not being acted on by rennin, leaving the stomach very rapidly.

Cereal Diluents.—Another method of hindering the formation of large, casein curds is by the addition of cereal diluents, such as barley water, to the food. The soluble starch in these cereal diluents acts as a protective colloid. The salts and the suspended cellulose probably play no part in the action of these diluents. It has been found that percentages of starch greater than 0.75 in milk mixtures have no more effect in diminishing the size of the curds than does 0.75%, while smaller percentages are less effective. When a cereal diluent is added to an infant's food for the purpose of preventing the formation of large, casein curds, it should, therefore, be added in such a way that the starch content of the mixture is 0.75%.

Boiling.—One of the most effective, as well as one of the simplest, methods of preventing the formation of large, casein curds is the boiling of the food. When rennin is added *in vitro* to raw milk and the mixture kept at the proper temperature, a dense, hard coagulum, which separates completely from the whey, is quickly formed. When rennin is added to boiled milk, however, coagulation takes place more slowly, and the curd which is formed is soft and fine. The separation of the curd and whey is also much less complete than in raw milk, so that the appearance of the liquid is that of a thick homogeneous fluid. The experiments of Brennermann [1] and others show that the same differences in the coagulation of the casein of raw and boiled milk by rennin exist in the stomach as *in vitro*. The food must be boiled hard at least five minutes in a single boiler in order to prevent the formation of large curds. Simmering in a double boiler is not effective.

Alkalis.—The addition of an alkali to milk unquestionably hinders or prevents the formation of large, hard curds in the stomach. There is much difference of opinion as to exactly how it does this and as to exactly what chemical changes take place in the gastric digestion of casein as the result of the addition of an alkali. The most probable explanation of these differences of opinion is that the exact details of the digestion of casein are even now but imperfectly understood. The nomenclature of the various products which are formed is, moreover, not a settled one. The

[1] Journal A. M. A., 1913, lx, 575.

coagulation of the milk in the stomach by rennin is unquestionably delayed by the addition of an alkali, because rennin does not act in an alkaline medium. How much it is delayed depends, with a given amount of alkali, on the acidity of the milk, which in clinical work is always an unknown quantity. The more acid the milk, the more of the alkali is required to neutralize it and the less is left to neutralize the hydrochloric acid secreted by the stomach and vice versa. When pure, clean milk is used, the part played by the acidity of the milk is probably relatively unimportant. During this period of delay it is generally believed that some of the uncoagulated milk leaves the stomach, the amount of milk which passes into the duodenum varying directly with the length of time before coagulation takes place. Certain authorities claim that the milk cannot leave the stomach under these conditions, because the pylorus does not open until the reaction on the stomach side is acid. Others state that milk, before it is coagulated, leaves the stomach quickly in gushes, like water, independent of the pyloric reflex.[1] When coagulation does occur the curds formed are more granular and softer than the tough curds of calcium paracasein which are ordinarily formed.

Whatever the action of the alkali may be, there is no doubt that it consists partly in neutralizing the acidity of the milk and partly in neutralizing the hydrochloric acid secreted by the stomach, thereby changing the combination of the calcium salts with casein. It is evident, therefore, that, as regards the neutralization of the acidity of the milk, whatever alkali is used, the amount to be added to the food should be determined by the amount of milk and cream in the food, which determine its acidity and which alone contain casein, not in relation to the total quantity of the mixture. It is impossible in ordinary clinical work to know how much alkali to add, because the acidity of the milk is always an unknown quantity. Experience has shown, however, that, when lime water is used as the alkali, from 25 to 50% of lime water must be added to average milk in order to produce any appreciable effect.

Bicarbonate of soda or other alkalis are sometimes used in place of lime water. One and one-half grains of bicarbonate of soda is equal to about an ounce of lime water. The action of lime water and bicarbonate of soda is, however, somewhat different. Lime water swells the mucoid protein of milk, which probably has some effect on the precipitation of the casein, while the carbonic acid gas which is formed from bicarbonate of soda during digestion tends to make the curds more porous.

[1] Cannon: The Mechanical Factors of Digestion, 1911, p. 115.

Citrate of Soda.—Citrate of soda is of considerable value in the prevention of the formation of large, tough curds. Under ordinary conditions rennin splits calcium caseinate into calcium paracaseinate which is insoluble. The citrate of soda combines with the calcium caseinate of the milk to form sodium caseinate and calcium citrate. Rennin splits sodium caseinate into sodium paracaseinate, which is very soluble. Therefore no precipitation or curdling takes place.[1] One or two grains of the citrate of soda to the ounce of milk or cream in the mixture is the quantity usually employed. Two grains to the ounce is probably more effective than one grain.

Buttermilk.—The casein in buttermilk and other forms of milk in which lactic acid forming organisms have been allowed to grow is in a form in which it cannot be acted upon by rennin. The formation of large, hard curds is, therefore prevented. The casein is said to be in the form of the lactate of casein, this having been formed as the result of the combination of the lactic acid produced by the bacteria with the casein. This statement seems very doubtful, however, as casein acts as an acid and two acids cannot combine. Some of the casein has also presumably been more or less digested by bacterial action. The casein in buttermilk is in a finely divided condition as the result of the mechanical action of the churning. Boiling buttermilk does not affect the chemical combination of the casein.

Protein Milk.—A considerable part of the casein in the so-called Eiweissmilch or, in English, protein or albumin milk, has already been precipitated by rennin in the form of calcium paracasein. When taken into the stomach it, therefore, cannot be acted upon again by rennin. The paracasein curds have been, moreover, very finely divided by being rubbed through sieves in the preparation of the food. The casein furnished by the buttermilk in the food is, as has already been explained, in the form of the "lactate of casein." The formation of large, tough curds in the stomach is, therefore, impossible.

Pancreatization.—Another method of preventing the formation of large curds is by the partial predigestion of the food. This is commonly known as peptonization but is in reality pancreatization, the active ferment being the trypsin of the pancreas. A part, at least, of the casein is so far digested that it cannot be acted upon by rennin. The formation of hard curds in the stomach is, therefore, more or less interfered with, the amount of interference

[1] Bosworth and Van Slyke: Technical Bulletin No. 34, New York Agricultural Experiment Station.

depending on how far the process of pancreatization has been carried.

Salts.—The various salts, with the exception of iron, are present in sufficient quantities and in proper proportions in human milk. In most modifications of cow's milk there is an excess of salts and the proportions of the various salts are different from those in human milk. The normal infant can, as a rule, thrive in spite of this excess of salts and in spite of their, for the infant, abnormal relation to each other. There is no doubt, however, that a part, perhaps a considerable part of the disturbances of digestion in infants fed on modifications of cow's milk are due to the excess and abnormal relations of the salts in them. It does not seem reasonable, nevertheless, to go as far as some pediatricians and attribute all the disturbances of digestion to them. At present, however, our knowledge concerning the salts, the part which they play in normal digestion and metabolism and the symptoms of the disturbances which they cause is so limited and incomplete that we can pay but little attention to them in the regulation of the diet either in health or in disease.

The Relation of the Different Elements of the Food to Each Other.—Thus far the different elements of the food and the disturbances of digestion to which they may give rise have been considered as if they always occurred independently of each other. This point of view is, however, a mistaken one. It is wrong to think so much, as is now the custom, of the disturbances of digestion caused by single elements of the food. There can be no doubt that in many instances in which the disturbance appears to be due to a single element, the real trouble is in the relation of the different elements to each other. Our knowledge of the connection of the disturbances of digestion with the various food elements is still extremely rudimentary, and we must be very careful not to accept each new item of information as the final solution of the problem.

Special Preparations of Milk used in Infant Feeding.—Various special preparations of milk have been used in infant feeding with, according to those who have employed them, unusually favorable results. The most important of them are buttermilk and protein milk.

Buttermilk.—Buttermilk made from sweet milk in the manufacture of butter is, of course, nothing but skimmed milk. It contains from 0.50% to 1.0% of fat, about 4.5% of milk sugar and 3.8% of protein, the relation of the casein and the whey protein being the same as in whole milk.

Buttermilk is usually made from cream soured either naturally

or by the addition of lactic acid bacteria. The composition of buttermilk obtained in this way is not a constant one. Average figures are: fat, 0.5% to 1.0%; milk sugar, 3.0% to 3.5%; protein, 2.5% to 2.7%. The proportion of whey protein is relatively higher than in whole milk. The casein is very finely divided as the result of the centrifugalization and is separated from its calcium base. It is already clotted in the form of the "lactate of casein" and can no longer be acted upon by rennin. The caloric value of buttermilk varies between 300 and 400 calories per liter. A fair average figure is 360 calories per quart.

Good buttermilk should not contain over 0.50% of lactic acid. There is a tendency for the acidity to increase with time, although it rarely reaches over 0.75%, at which point the buttermilk separates into curds and whey. The lactic acid organisms which caused the souring of the milk, as well as other organisms, are alive and active. Heating buttermilk destroys the fine division of the casein and causes it to clot in large masses like ordinary cow's milk. It also destroys the bacteria which it contains. Heated buttermilk is, therefore, no better than sour skimmed milk. This clotting may be prevented by constant, violent stirring or beating while it is being heated.

Buttermilk has been used as a food for infants since at least as early as 1770, and good results have unquestionably been obtained with it. This is readily understood when its composition is remembered. It contains a low percentage of fat, a rather low percentage of sugar and a relatively high percentage of protein, the proportion of whey protein being relatively greater than in plain milk. The casein is finely divided and in a form which cannot be acted on by rennin. It is highly acid from the presence of lactic acid and contains many bacteria, the lactic acid forms predominating. It should be useful, therefore, in those conditions in which a low fat and a high, easily digestible protein is indicated. The lactic acid organisms which it contains should also be of advantage in those disturbances of digestion which are due to organisms to which the lactic acid bacteria are antagonistic. This possible advantage is lost, of course, when buttermilk is pasteurized or boiled.

Most of those who have employed and recommended the use of buttermilk as a food for infants have, however, not used it plain. They have added from 10 to 25 grams of flour, usually wheat, and from 35 to 90 grams of cane sugar to a liter of buttermilk and then boiled it with much stirring. The nutritive value of the buttermilk is thus materially increased, while the other characteristics are unchanged, except that the lactic acid bacteria are

destroyed. The caloric value of buttermilk prepared in this way varies between 525 and 700 calories per liter, the additional calories being furnished by the cane sugar and starch which have been added.

It does not seem rational to use buttermilk, with or without the addition of cane sugar and starch, as a routine food for all babies, whether sick or well. It is far more reasonable to adopt the good points in it and utilize them in combination with percentage feeding.[1] There is no special advantage in using buttermilk in cases in which a low percentage of fat is indicated, because a low percentage of fat can be more easily given in other ways. The peculiar form of the casein in buttermilk may be of considerable value in instances in which there is a disturbance of the digestion of casein. If plain buttermilk or stock preparations of buttermilk are used, the percentages of fat and sugar cannot be varied to suit the needs of the individual baby. If a modified milk is prepared to fit the needs of the individual infant at the time and the character of the casein then changed by the action of lactic acid bacteria, the chief advantage of buttermilk is thus retained and yet the food is in other ways fitted to the needs of the baby. It is probable that the degree of the acidity of the buttermilk plays some part in its action. This cannot be regulated in commercial buttermilk, but can be when the milk is soured by the addition of lactic acid bacteria, since the production of acid can be stopped at any time by boiling the mixture. When the change in the character of the protein is all that is desired, the mixture should be boiled when the acidity is between 0.25% and 0.50%. Twenty-five hundredths per cent of lactic acid just curdles milk while 0.50% gives thick curdled milk. An acidity of from 0.50% to 0.70% is usually attained in from twelve to eighteen hours.

When the action of the lactic acid bacteria on the intestinal bacteria is what is desired, the mixture should not, of course, be boiled. The acidity should not, however, run much above 0.50%.

Other objections to the use of commercial buttermilk are that the acidifying organisms are usually of several varieties and that the milk contains a variety of other organisms which have grown at the same time, many of which are undesirable. It is far wiser, therefore, to prepare foods for babies by the addition of pure cultures of lactic-acid-forming organisms to pure or boiled milk. The danger of infection by other organisms is thus avoided. The bacillus Bulgaricus is the one perhaps most commonly used. It is liable, however, to make the taste of the milk too acid. Another

[1] Morse and Bowditch: Archives of Pediatrics, 1906, xxiii, 889.

organism, perhaps better, is the bacillus acidi paralactici. Cultures of lactic-acid-forming organisms are now easily obtainable from milk laboratories and chemists. Better results are usually obtained by the use of a "starter" than by the use of a new culture each time.[1] Cultures are much preferable to the various lactic acid tablets on the market, many of which are inert and none of which are as active as cultures.[2]

Protein Milk (*Eiweissmilch, Casein Milk, Albumin Milk*).—Finkelstein and Meyer conclude from their observations that sugar is the special and primary cause of intestinal fermentation and that the fat is never involved primarily. They believe that the fermentation of the sugar is dependent on two main factors: the concentration of the whey and the relative proportions of casein and sugar in the mixture. They conclude, therefore, that the principles on which the preparation of a food to combat intestinal fermentation depend are: a diminution in the quantity of milk sugar, a diminution of the salts through dilution of the whey, and an increase in the casein, with varying, and, under certain circumstances, not inconsiderable amounts of fat. After improvement has begun, an easily assimilable and consequently little fermentable carbohydrate should be added. They consequently developed a food to meet these indications to which they gave the name of Eiweissmilch. This food is prepared as follows: Heat one quart of whole milk to 100° F. Add four teaspoonfuls of essence of pepsin and stir. Let the mixture stand at 100° F. until the curd has formed. Put the mass in a linen cloth and strain off the whey from the curd. Remove the curd from the linen cloth and press it through a rather fine sieve two or three times by the means of a wooden mallet or spoon. Add one pint of water to the curd during this process. The mixture should now look like milk and the precipitate must be very finely divided. Add one pint of buttermilk to this mixture.

Finkelstein and Meyer used buttermilk in the preparation of this food for the following reasons: 1, because of the small amount of milk sugar which it contains; 2, to obtain the good effects of the lactic acid, and 3, because buttermilk can be kept for a long time.

The composition of this food is:

Fat	2.5%
Sugar	1.5%
Protein	3.0%
Salts	0.5%

[1] Morse and Bowditch: Archives of Pediatrics, 1906, xxiii, 889.

[2] Heinemann: Jour. Amer. Med. Ass'n, 1909, lii, 372, and 1912, lviii, 1252.

One quart of this milk contains about 370 calories.

They call attention to the low caloric value of this food and to the necessity of increasing it as soon as possible by the addition of dextrin-maltose mixtures.

They claim that it is worthy of employment in all the disturbances of nutrition in infants which are accompanied by diarrhea of no matter what sort or variety. The use of this food has been extended by others to all sorts of conditions, including the feeding of well infants and the newly-born, and good results claimed for it.

The principle of the treatment of fermentative conditions caused by sugar with a food low in sugar and salts and high in protein is a rational one, as is the substitution of the dextrin-maltose mixtures for lactose. It hardly seems rational, however, to believe that all disturbances of nutrition accompanied by diarrhea are due to the same cause and should be treated in the same way. Neither does it appear reasonable to think that any method of feeding can be applicable to both the sick and the well or to give all babies the same food without regard to their individual digestive capacities.

It is possible, however, to take advantage of the main principles of this method of treatment of the intestinal fermentative conditions and at the same time avoid the disadvantages of a routine food by applying them in the modification of milk by the percentage method. The buttermilk seems to be an unnecessary addition, because the low salt and high casein content, which form the *raison d'être* of the food, can be obtained perfectly well without it. It is possible by the use of cream containing a high percentage of fat to reduce the amount of unprecipitated casein and whey protein to a very small percentage and yet have any desired percentage of fat in the mixture. The percentages of salt and sugar are also kept low because of the small amount of cream required. Any percentage of casein desired can then be added in the form of precipitated casein prepared according to Finkelstein and Meyer's method. The advantages of this method of treatment of fermentative intestinal conditions are retained in this way and the disadvantages of a routine method avoided. The dextrin-maltose mixtures can be added, of course, when desired, and the percentage of salt increased by the substitution of creams containing lower percentages of fat.

The preparation of protein milk and of modifications of milk made with precipitated casein is a difficult matter outside of milk laboratories or institutions. This method of treatment is, therefore, hardly applicable in the home. The addition of dried, pow-

dered casein and paracasein to mixtures made in the ordinary way, as suggested by Bowditch and Bosworth [1] offers another method of combining low percentages of sugar and salts with a high percentage of casein. This method is, moreover, much simpler and can be carried out in the home as well as in institutions or milk laboratories.

[1] Amer. Jour. Diseases of Children, 1913, vi, 394.

CHAPTER XVIII

THE PRESCRIBING OF MODIFIED MILK

The first thing to do in prescribing modified milk for an infant is to determine what percentages of fat, sugar, protein and starch shall be in the mixture. The next things to decide are whether the sugar shall be in the form of milk sugar, cane sugar or one of the dextrin-maltose mixtures and whether a part of the protein shall be given in the form of whey protein or not. It is then necessary to determine whether an alkali shall be added or not and, if it is added, what form shall be used and how much of it. Finally it must be decided whether the mixture shall be given raw, pasteurized, and if so, at what temperature, or boiled. After all these points are settled, the number of feedings and the amount at each feeding must be decided, bearing in mind in this connection that the total quantity given in the twenty-four hours is far more important than the number of feedings and the size of the individual feeding. It is advisable, after deciding upon the total quantity, to calculate the caloric value of the food and the amount of protein which it contains in order to know whether the caloric and protein needs are being covered or greatly exceeded. In most instances the food decided upon should be given, even if its caloric and protein content do not correspond to the established standards. The knowledge of these points will, however, often prove of great assistance in changing the food in the future, if the baby does not thrive on it. In special cases it is also necessary to determine whether the mixture shall be acted upon by lactic acid organisms or not, and, if so, whether or not they shall be destroyed by heat; in others, whether some form of protein milk (Eiweissmilch) shall be used or the milk pancreatized.

Every one of these points must be decided every time that a modified milk mixture is prescribed. No single one of them can be omitted. They must be decided, moreover, not by following blindly the rules of some authority on infant feeding or by picking a formula from a table in some text-book, but on the indications in the given case at the given time.

When the composition and the amount of the food have been decided, the food may be prepared either at a milk laboratory or in

the home. When the milk is to be prepared at a milk laboratory, it is only necessary to write a prescription for the food, embodying the points already determined. Most milk laboratories have a prescription form in which it is only necessary to fill in the blank spaces. This form, while a convenience, is in no way a necessity. The physician who is competent to prescribe modified milk mixtures has no need of a form. On page 214 is a copy of the prescription form furnished by the milk laboratories in the neighborhood of Boston.

There is no doubt that a milk laboratory can prepare mixtures of modified milk more accurately than they can be prepared in the home. The milk and cream can be analyzed daily in the laboratory and the sugar and starch accurately weighed, so that the mixtures can be made from materials of known composition. This cannot be done in the home. Whether the formulæ are actually put up more accurately in the laboratory than in the home depends, however, on the care exercised in the individual laboratory at the given time. The employees in milk laboratories are human and are, therefore, liable to be careless and to make mistakes. Another advantage which the milk laboratories have is that they own their own farms and can, therefore, be sure of having a clean milk from which to prepare the food. The individual preparing the food at home, unless able to procure a certified milk, can never be sure whether the milk is clean or not.

The price of modified milk, prepared at milk laboratories, is no higher than it should be, when the character of the materials used, the labor required in the modification of the milk and the cost of delivery are taken into consideration. The price is, nevertheless, prohibitive for poor people. If the milk has to be sent any distance and express charges added, only the well-do-to can afford to have it. Comparatively few babies can be fed, therefore, on modified milk prepared at a milk laboratory. The vast majority, either because of the expense or the distance from a laboratory, must be fed on mixtures prepared in the home.

THE HOME MODIFICATION OF MILK

Modifications of milk for infant feeding cannot be prepared as accurately in the home as at a milk laboratory, because it is impossible in the home to know the exact composition of the materials used in the preparation of the mixtures. If reasonable care is used in their preparation, however, the inaccuracies are not as great as would be supposed. In fact, in the vast majority of instances,

℞		Per Cent.	
Fats			
(a) Carbohydrates	Lactose (Milk Sugar) Maltose (Malt Sugar) Sucrose (Cane Sugar) Dextrose (Grape Sugar) Starch		
(b) Dextrinize			
(c) Proteids	Whey Casein		
(d) Peptonize			
(e) Sodium Citrate	% of milk and cream % of total mixture		
(f) Sodium Bicarb.	% of milk and cream % of total mixture		
(g) Lime Water	% of milk and cream % of total mixture		
(h) Lactic Acid Bacillus	1 To inhibit the saprophytes of fermentation 2 To facilitate digestion of the proteids		

Heat at ______ °F. ______

Number of Feedings ______

Amount at each Feeding ______ oz.

ORDERED FOR

______

ADDRESS______

DATE______ 19

______M. D.

EXPLANATORY

(a) It requires 0.75% starch to make the precipitated casein finer.

(b) One hour completely dextrinises the Starch.

(c) In case physicians do not wish to sub-divide the proteids, the words "Whey" and "Casein" may be erased.

(d) Twenty minutes renders the mixture decidedly bitter.

(e) It requires 0.20% of the milk and cream used in modifying to facilitate the digestion of the proteids; *i. e.*, the formation of a soft curd. 0.40% to prevent the action of rennet; *i. e.*, the formation of tough curd.

(f) It requires 0.68% of the milk and cream used in modifying to favor the digestion of the proteids. 1.70% of the amount of milk and cream used suspends all action on the proteids in the stomach. 0.17% of the total mixture gives a mild alkaline food.

(g) It requires 20% of the milk and cream used in modifying to favor the digestion of the proteids. 50% of the amount of milk and cream used suspends all action on the proteids in the stomach. 5% of the total mixture gives a mild alkaline food.

(h) Percentage figures represent the per cent of Lactic Acid attained when the food is removed from the thermostat. When the Lactic Acid Bacillus is used to facilitate digestion of the proteids, this is the final acidity, as the process is stopped by heat at this point. When the Lactic Acid Bacillus is used to inhibit the growth of saprophytes, the acidity may subsequently increase to a variable degree, as the bacilli are left alive. 0.25% Lactic Acid just curdles milk. 0.50% gives thick curdled milk. 0.75% separates into curds and whey.

they are not great enough to disturb the digestion or to interfere with the nutrition and development of babies fed upon them. The average infant fortunately does not notice small variations in the composition of an artificial food any more than it does similar variations in the composition of breast-milk. Extreme accuracy is necessary only in exceptional cases. In general, therefore, the modifications of milk prepared at home are sufficiently accurate for all practical purposes and it is rarely necessary on this account to have recourse to a milk laboratory. When practicable, it is, however, much easier, and in most instances will be found more satisfactory, to have modified milk prepared at a laboratory rather than at home.

It is often said that the calculation of the formulæ for the preparation of modified milk at home is too complicated for the average physician to carry out and that it requires more time than the busy practitioner can give to it. These statements are distinctly not true. There is nothing about the calculation of formulæ sufficiently accurate for practical purposes which cannot be understood by anyone with even an elementary knowledge of arithmetic. If a physician cannot understand the principles involved, there must have been some mistake made when his degree was granted. There is no more reason why a physician should not take the time to calculate a proper modification of milk for a baby than why he should not take the time to sterilize his hands before an abdominal operation. He is equally negligent in either case, if he does not. As a matter of fact, however, it requires but little time to calculate a formula, if the physician knows how to do it. Five or, at the most, ten minutes is amply sufficient.

It is also not infrequently said that the procedures involved in the preparation of modifications of milk in the home are too complicated for the ordinary mother or nurse maid to comprehend and carry out. This statement is also untrue. There is nothing about the preparation of modified milk in the home which any woman of average intelligence cannot understand and do, provided it is properly explained to her. The trouble is not with the women, but with the physicians who, either through ignorance or carelessness, neglect to explain the details of the preparation of the food to them.

In prescribing for modified milk to be prepared in the home it is necessary to determine not only what food shall be given to the baby, but also how this food shall be prepared. It is of great importance, in the first place, to be sure that the milk which is to be used is a clean milk. It is impossible to make a good food from dirty milk, no matter how much it is modified.

It is also of considerable importance to employ milk which is reasonably constant in its composition. This is best done by using certified milk. Modifications prepared from ordinary milk, provided it is not from Jersey cows or similar breeds, are, however, in most instances sufficiently accurate in places where there is a legal standard for milk. When there is a doubt as to the composition of the milk, it is not a difficult matter to determine it approximately.

The fat content of milk can be accurately determined in a few minutes with one of the small hand Babcock milk testers. A very satisfactory two bottle machine, The "Facile Jr.," is made by D. H. Burrell and Co., of Little Falls, N. Y. The price with bottles, pipette and measuring glasses is $4.50. It is important in making this test to use sulphuric acid of a specific gravity of from 1.82 to 1.83 at 60° F. The total solids can be easily determined in a few minutes with a lactothermometer and a Richmond "Milk Slide Rule." These, with directions for their use, may also be procured of D. H. Burrell and Co., the price of the lactothermometer being from $1.00 to $1.50, and that of the Richmond "rule" $2.50. The percentage of fat and the total solids being known and the percentages of the ash and sugar being fairly constant, the percentage of the protein can be approximately determined with reasonable accuracy by subtracting the sum of the percentage of fat and the estimated percentages of the sugar and ash from the percentage of the total solids. The percentage of casein can be readily determined in from fifteen to twenty minutes by the volumetric method of Van Slyke and Bosworth, if more accurate results are desired.[1] Multiplying the percentage of casein by 1.4 gives the percentage of the total protein accurately enough for practical purposes.

Composition of Materials used in the Home Modification of Milk.—It being impossible, except in rare instances, to analyze the milk and cream used in the preparation of modified milk in the home, it is necessary to adopt certain arbitrary standards as to the composition of these substances. It must be remembered that any form of milk containing more than 4% of fat is technically cream. It is wrong, therefore, to think and speak of cream as a definite entity, without qualification. It is more correct to think of creams, with the fat content always specified. The following figures (Table 43) as to the composition of the various creams, whole milk, skimmed milk and whey are approximately correct.

[1] New York Medical Journal, 1909, xc, 542.

TABLE 43

	Fat	*Milk sugar*	*Protein*
Whole milk	4.00	4.50	3.50
7% cream	7.00	4.45	3.40
10% cream	10.00	4.40	3.25
16% cream	16.00	4.20	3.05
32% cream	32.00	3.40	2.50
Skimmed milk	1.00	5.00	3.55
Separated milk ("fat free")	0.25	5.00	3.65
Whey	0.25	5.00	0.90

If milk is allowed to set six hours or longer, the upper sixteen ounces of a quart of bottled milk contains 7% and the upper ten ounces 10% of fat. The cream layer, that is "gravity cream," without regard to how many ounces of it there are on a quart, contains about 16% of fat. If the whole milk from which cream is obtained contains more than 4% of fat, the cream will contain a proportionally larger amount. Ordinary "thick cream," as it is called, contains, on the average, 32% of fat. The composition of this type of cream is, however, very variable, so variable indeed that it is hardly safe to use it in the preparation of modified milk, unless the percentage of fat is known.

Skimmed milk is the milk which is left after the gravity cream has been removed by a dipper or by pouring. If some of the upper layers of the milk are removed in addition to the cream, the part which is left contains less than 1% of fat. Separated ("fat free") milk is the milk which is left when the cream has been removed by centrifugalization. The whey obtained from separated milk contains 1% of protein.

Table 44 copied from Chapin and Pisek,[1] shows the percentage of fat in each of the top nine ounces of a quart of bottled milk which has set six hours or longer, and the fat content of the top ounces, from two ounces to thirty ounces, under the same conditions.

It is evident that "top milk" may mean any number of ounces, from one to thirty-one ounces, from a quart. It is also evident that the so-called "top milks" are merely creams of varying percentages and that modifications of milk made from "top milks" differ in no way from those made from creams except in name. Since top milks vary as much in their fat content as do creams, it is evidently just as important in prescribing for the preparation of

[1] Diseases of Children, 1909, p. 138.

TABLE 44

First ounce contains	25.0%	fat
Second " "	23.0%	"
Third " "	19.0%	"
Fourth " "	18.5%	"
Fifth " "	10.5%	"
Sixth " "	4.8%	"
Seventh " "	3.4%	"
Eighth " "	2.2%	"
Ninth " "	1.8%	"

Top 2 ounces mixed contain	24.0%	fat
3 " " "	22.5%	"
4 " " "	21.4%	"
5 " " "	19.2%	"
6 " " "	16.8%	"
7 " " "	15.0%	"
8 " " "	13.3%	"
9 " " "	11.5%	"
10 " " "	10.5%	"
12 " " "	9.0%	"
14 " " "	7.8%	"
16 " " "	7.0%	"
18 " " "	6.3%	"
20 " " "	5.8%	"
22 " " "	5.4%	"
24 " " "	5.0%	"
26 " " "	4.7%	"
28 " " "	4.5%	"
30 " " "	4.3%	"

modified milk at home to specify exactly what top milk is to be used as it is to specify what sort of cream is to be used.

Method of Calculation of Formulæ for the Home Modification of Milk.—There are many methods for the calculation of the formulæ for modifications of milk to be prepared in the home. Most of them are inaccurate in that the fat in the skimmed milk is disregarded, many of them in that the percentage of protein in the cream and skimmed milk is considered to be the same. All of them are accurate enough, however, for everyday work. It makes but little difference which method is employed, provided that method is understood and used correctly. It makes no difference whether gravity cream, 10% cream, top milks, skimmed milk or whole milk are used in the preparation of the mixtures. Equally good results can be obtained with all. The one important thing is that the food be calculated in percentages of the various food elements. It makes little difference how these elements are obtained. Methods which take the fat in the skimmed milk and the differences in

the protein content of the various creams and milks into account are too complicated for ordinary, clinical use and are, fortunately, unnecessary. Those who wish to familiarize themselves with these different methods can find them fully described in two articles by Westcott.[1]

The writers have found the following method of calculation a satisfactory one in their own practice and have found that medical students understand it quickly and apply it easily and these are its chief recommendations. It is unquestionably inaccurate in many ways, as are all simple methods of calculation. It must be remembered, however, in criticizing methods of calculation for their inaccuracies, that, if the same method is used consistently, the inaccuracies are always similar and that different modifications of milk prepared by the same method are accurate relatively to each other. That is to say, if a baby who is taking a mixture supposed to contain 3.50% of fat, but which really contains 4% of fat, shows symptoms of fat indigestion, a reduction of 0.50% in the percentage of fat will have the same effect in relieving these symptoms, although it is a reduction from 4% to 3.50% instead of one from 3.50% to 3%, as it is supposed to be. That is, changes in the percentages are correct, even if the original percentages are incorrect.

Gravity cream and skimmed milk are used in this method. The gravity cream is estimated to contain 16% of fat and the skimmed milk to be fat free. The mixtures, therefore, all contain a somewhat higher percentage of fat than they are supposed to contain. The protein content of both the gravity cream and the skimmed milk is calculated to be 3.20%. This percentage is higher than that really present in the cream and lower than that in the skimmed milk. Numerous analyses, made by us by the Kjeldahl method, of the protein content of mixtures prepared in this way have shown, however, that the percentage of protein in them is not far from what it is calculated to be. They are much more nearly correct than would be expected. The percentage of sugar is estimated at 4.50 in both the gravity cream and skimmed milk.

It may be well to define what is meant by gravity cream and skimmed milk once more before describing the method of calculation. By gravity cream is meant all the cream which is visible on milk which has set for six hours or longer. All the cream must be

[1] The Scientific Modification of Milk. International Clinics, 1900, Tenth Series, iii, 233, and A Method for the Differential Modification of the Proteids in Percentage Milk Mixtures. American Journal Medical Sciences, 1901, cxxii, 439.

removed and the required number of ounces taken from it. If there is not enough cream on one bottle, the cream must be removed from two bottles and mixed. The required number of ounces is then taken from the mixture of the two. The cream may be removed with a cream dipper or it may be poured off. The results obtained by pouring are not as accurate as those obtained by dipping. The same result may be obtained by siphoning off the milk below the cream and leaving the cream in the bottle. When a cream dipper is used, the first ounce must, of course, be removed with a spoon or the milk will be spilled when the dipper is introduced. Most bottled milk has been in the bottles many more than six hours before it is delivered. When the milk bottle is full, the cream rises even during transportation. It is not necessary, therefore, to wait six hours after the milk is delivered before preparing the food, provided the cream line is distinct.

By skimmed milk is meant what is left after the gravity cream has been removed. The percentage of fat in the mixture will be more nearly correct if the lowest ounces are used instead of the same number of ounces from the whole of the skimmed milk.

A rounded tablespoonful of milk sugar is considered in this method of calculation to weigh one-half an ounce. It will be found that this is not far from the true weight. By a rounded tablespoonful is meant what is contained in a tablespoon when it is dipped into milk sugar and then gently shaken, that is, it is rounded, not heaped or level. Every cook knows what is meant by this term. The weight of equal quantities of milk sugar and the dextrin-maltose mixtures is nearly enough the same for practical purposes.

The estimated composition of the materials used in the preparation of the mixtures is, therefore, as follows:

TABLE 45

	Fat	*Milk sugar*	*Protein*
Gravity cream	16.00%	4.50%	3.20%
Skimmed milk	0.00%	4.50%	3.20%
Milk sugar	1 rounded tablespoonful = ½ ounce.		

It is necessary, as always, before beginning the calculations as to the preparation of the food, to decide what percentages of fat, sugar and protein the food is to contain, how much is to be given in the twenty-four hours and how much lime water, if any, is to

be added. It is usually advisable to make the quantity large enough to allow for an extra bottle, so that, if a bottle is broken, the baby need not go hungry.

Suppose that it is desired to prepare thirty-two ounces of a mixture containing 3% of fat, 6% of milk sugar and 2% of protein, with lime water enough to equal 25% of the milk and cream in the mixture. The fat in the food must be derived from the cream, because it is the only substance containing fat to be used in the preparation of the food. If the food was composed entirely of gravity cream it would contain 16% of fat. Since it is to contain but 3% of fat, it is evident that only three-sixteenths of the mixture must be gravity cream; $\frac{3}{16}$ of thirty-two ounces is six ounces. Six ounces of gravity cream will, therefore, provide the 3% of fat desired in the mixture.

The gravity cream contains protein as well as fat. There are six ounces of gravity cream in the thirty-two-ounce mixture. The protein content of gravity cream is 3.20%. The protein content of a thirty-two-ounce mixture containing six ounces of gravity cream is evidently $\frac{6}{32}$ of 3.20%, or 0.60%. Two per cent of protein is however, desired in the mixture. The gravity cream has provided only 0.60%. One and forty hundredths per cent of protein, the difference between the percentage of protein desired and that furnished by the gravity cream, must be obtained in some other way. It must be obtained, moreover, from some substance which does not contain fat. Skimmed milk is such a substance. Skimmed milk contains 3.20% of protein. In order to get 1.40% of protein in the mixture by the use of skimmed milk, it is evident that $\frac{1.40}{3.20}$ of the mixture must be skimmed milk; $\frac{140}{320}$ of thirty-two ounces is fourteen ounces. Fourteen ounces of skimmed milk will, therefore, provide the additional 1.40% of protein desired.

Both gravity cream and skimmed milk contain 4.50% of milk sugar. Twenty ounces of gravity cream and skimmed milk are required to furnish the desired percentages of fat and protein. These twenty ounces in a thirty-two-ounce mixture must add $\frac{20}{32}$ of 4.50% of sugar to the mixture. Twenty thirty-seconds of $4\frac{1}{2}$, or $\frac{20}{32}$ of $\frac{9}{2} = \frac{180}{64}$, or practically 3% of milk sugar. It is, however, desired to have 6% of milk sugar in the mixture. That is, 3% more of milk sugar is required. This additional sugar must be added in the form of dry milk sugar. Three per cent of thirty-two ounces is $\frac{3}{100}$ of thirty-two. This will give the amount of sugar desired in ounces. The sugar is to be measured in rounded tablespoonfuls, or half ounces. If the figures given above are multiplied by two, the result will be the number of rounded tablespoonfuls needed.

That is, $\frac{3}{100}$ of 32 x 2 = $\frac{192}{100}$ rounded tablespoonfuls, or for all practical purposes, two rounded tablespoonfuls.

It is also desired to have an amount of lime water in the mixture equal to 25% of the cream and milk in the mixture. There are twenty ounces of cream and milk in the mixture. Twenty-five per cent of twenty ounces is five ounces. Five ounces of lime water must, therefore, be added. The total quantity of the mixture is to be thirty-two ounces. The mixture is to contain six ounces of gravity cream, fourteen ounces of skimmed milk and five ounces of lime water, that is, twenty-five ounces. The milk sugar goes into solution and, therefore, does not add to this quantity. The difference between thirty-two ounces and twenty-five ounces is seven ounces. Seven ounces of water must, therefore, be added to make up the quantity desired. The following table shows the results of the steps just described.

TABLE 46

	Ounces	*Fat*	*Sugar*	*Protein*
Gravity cream	6	3.00	3.00 (cream and milk)	0.60
Skimmed milk	14			1.40
Milk sugar	2 rounded tablespoonfuls		3.00	
Lime water	5			
Water	7			
	32	3.00	6.00	2.00

The milk sugar should be dissolved in the seven ounces of hot water. The water should be allowed to cool and then be mixed with the other ingredients.

Mixtures containing Starch.—It is as important to have the percentage of starch in the food accurate as it is to have those of the fat, sugar and protein. Starch is usually added in the form of the cereal waters. The strength of the cereal water which is to be used in the preparation of the food must be known, therefore, in order to get the desired percentages of starch in the mixture.

Two rounded teaspoonfuls of barley or oat flour to the pint of water give a 1.50% decoction of starch, while four rounded teaspoonfuls to the pint of water give a 3% decoction. The flour should be mixed with a small amount of water, after which the remainder of the water is added. The mixture is then boiled for twenty minutes, after which, as some of the water has boiled away, enough hot water is added to make up the original pint. It should

then be strained through several thicknesses of cheesecloth. It should be cooled before being mixed with the milk and cream.

If it is desired to have 0.75% of starch in a mixture and a cereal water containing 1.50% of starch is to be used, it is evident that one-half of the mixture must be made up of the cereal water. If a 3% cereal water is used, one-quarter of the mixture will be required to give 0.75% of starch. Suppose that it is desired to have 0.75% of barley starch in the mixture which has just been calculated. In order to get 0.75% of starch in a thirty-two-ounce mixture, using 1.50% barley water, it will be necessary to use $\frac{.75}{1.50}$ of thirty-two ounces, or sixteen ounces. The mixture already contains twenty-five ounces of gravity cream, skimmed milk and lime water, leaving room for only seven ounces of barley water. It is plain, therefore, that it is impossible to have 0.75% of starch in the mixture, if 1.50% barley water is used. If 3.00% barley water is used, $\frac{0.75}{3.00}$ of thirty-two ounces, or eight ounces will be required. There is room for only seven ounces. The difference in the percentage of starch added when seven or eight ounces are added is only 0.10%, which is a negligible amount. Seven ounces of 3.00 barley water will, therefore, be sufficient.

If preferred, the amount of starch to be added to a mixture to give any percentage required of starch in the mixture may be calculated directly. Suppose, for example, it is desired to have 1.00% of barley starch in a forty-eight-ounce mixture. One per cent of forty-eight ounces is $\frac{1}{100}$ of forty-eight ounces, or practically one-half an ounce. Two rounded teaspoonfuls or one rounded tablespoonful of barley flour weighs one-half an ounce and will, therefore, add 1% of barley starch to the mixture. This amount of barley flour should be cooked in the number of ounces of water in the mixture and then mixed with the gravity cream and skimmed milk.

Whey Mixtures.—It is impossible to make mixtures containing a high percentage of whey protein with a low percentage of casein, provided they contain more than one or 2% of fat, if gravity cream is used in the preparation of the food, as it usually is in the home. The reason of this is that the gravity cream which it is necessary to use in order to get the desired percentages of fat contains a considerable amount of protein and by its bulk diminishes the amount of whey and consequently the amount of whey protein which can be added. It is usually desired, when whey protein is prescribed, to have as much of it in a mixture as is possible. For practical purposes, therefore, when whey mixtures are prepared in the home with gravity cream, the amount of gravity cream required to give

the desired percentage of fat is calculated and the rest of the mixture made up with whey, the amount of whey protein added being determined later. Smaller percentages of whey protein can be added, of course, if desired.

Suppose that it is desired to give a baby a twenty-four-ounce mixture containing 3% of fat and 6% of sugar, with lime water 10% of the cream in the mixture; $\frac{3}{16}$ of twenty-four ounces is four and one-half ounces. Four and one-half ounces of gravity cream will, therefore, be required. This will put $\frac{4\frac{1}{2}}{24}$ of 3.20%, or 0.60%, of protein in the mixture. This protein is chiefly in the form of casein. Ten per cent of four and one-half ounces is nearly one-half an ounce. One-half an ounce of lime water must, therefore, be added. It is evident that there is room for nineteen ounces of whey in the mixture, the difference between twenty-four and $4\frac{1}{2} + \frac{1}{2}$, being nineteen. The composition of whey for practical work in the home modification of milk may be calculated to be $\frac{19}{24}$ of 0.90% of whey protein gives 0.70 of whey protein, which is the amount added by the whey.

	Fat	*Milk sugar*	*Whey protein*
Whey.................	0.00	4.50	0.90

Both the gravity cream and the whey contain 4.50% of milk sugar. There being but one-half ounce of lime water in the whole mixture, it already contains approximately 4.50% of milk sugar. It being desired to have 6% of milk sugar in the mixture, 1.50% more must be added in the form of dry milk sugar; $\frac{1\frac{1}{2}}{100}$ of 24 x 2 = 0.72 of a rounded tablespoonful. A level tablespoonful of milk sugar will, therefore, just about make up the required percentage of sugar.

The mixture contains 3% of fat, 6% of sugar, 0.70% of whey protein and 0.60% of casein. It is evident, therefore, that, if gravity cream is used, it is impossible to get less than 0.60% of casein in the mixture with 3% of fat, or less than 0.80 of casein with 4% of fat. The percentage of whey protein in the mixture is really somewhat higher and that of the casein somewhat lower than has been calculated, because about one-quarter of the protein furnished by the cream is in the form of whey protein. It is not necessary for every-day work, however, to take these small differences into consideration.

Higher percentages of whey protein and lower percentages of casein can be obtained with given percentages of fat, if creams

containing higher percentages of fat are used. It is possible, for example, even in the home, to get cream containing 24% of fat by taking only the top two ounces off of the quart.

It is also possible to have any percentage of casein desired with a given percentage of fat by using skimmed milk in the mixture. The amount of whey protein which can be put in the mixture is, of course, correspondingly diminished. When it is desired to work off of a whey mixture on to an ordinary mixture without increasing the total amount of protein, it is best done by gradually replacing the whey by skimmed milk and water. One ounce of skimmed milk and three ounces of water contains approximately the same amount of protein as four ounces of whey.

Preparation of Whey.—Put a pint of skimmed milk into a clean saucepan and heat it until it is lukewarm (not over 100° F.). Take off of the stove. Add two teaspoonfuls of essence of pepsin or liquid rennet, or two junket tablets. Stir just enough to mix. Let it stand until firmly jellied. Then break up with a fork until it is finely divided. Strain through a linen cloth or several thicknesses of cheesecloth. What goes through is whey. If whey is to be mixed with cream, milk or skimmed milk, it must be brought to 150° F. in order to kill the rennin. If whey is not brought to this temperature before it is added to milk or cream, the rennin in it will curdle them. It should be cooled before being mixed with cream or milk.

The Determination of Percentages in Mixtures.—It is often of great importance to find out just what a baby has been taking in order to know how to change the food, if it is not agreeing with it. To do this it is necessary to determine the percentages of the different elements in the food. This is not a difficult matter. Suppose that a baby is taking a food made up as follows:

Gravity cream	12 ounces
Skimmed milk	18 ounces
Lime water	6 ounces
Barley water	12 ounces
Milk sugar	4 rounded tablespoonfuls

The barley water is made with two teaspoonfuls of barley flour in a pint of water.

The total quantity of the mixture is forty-eight ounces. Gravity cream contains 16% of fat. Twelve ounces of gravity cream in a forty-eight-ounce mixture will give, therefore, 12/48 of 16% of fat, or 4% of fat. Both gravity cream and skimmed milk contain 3.20% of protein. There are thirty ounces of gravity cream and

skimmed milk in the mixture. Thirty ounces in a forty-eight-ounce mixture will give 30/48 of 3.20% of protein, or 2.00% of protein. Both the gravity cream and the skimmed milk also contain 4.50% of sugar. Thirty ounces of gravity cream and skimmed milk in a forty-eight-ounce mixture will, therefore, furnish 30/48 of 4½, which is the same as 30/48 of 9/2, or almost 3.00% of milk sugar. Four rounded tablespoonfuls of milk sugar are equal to two ounces. Two ounces of sugar in a forty-eight-ounce mixture is equal to 2/48 of 100%, or 4%. The total percentage of sugar is, therefore, 7%. Two teaspoonfuls of barley flour in a pint of water makes a 1.50% decoction of starch. Twelve ounces of barley water of this strength in a forty-eight-ounce mixture will give 12/48 of 1.50% or about 0.35% of starch. There are six ounces of lime water in the mixture and thirty ounces of gravity cream and skimmed milk; 6/30 of 100% is 20%. The lime water in the mixture is, therefore, 20% of the milk and cream. The mixture thus contains 4% of fat, 7% of milk sugar, 2% of protein and 0.35% of starch, while the lime water is present in the proportion of 20% of the cream and milk.

Method of Determining the Caloric Value of Mixtures of Modified Milk.—The method detailed below is longer than some of the other methods in common use. It is more accurate than many of them, however, and has this in its favor, namely, it is impossible to carry it out without fully understanding what the caloric value of food really means.

Suppose that a baby is taking thirty ounces of a food containing 4% of fat, 6% of sugar, 2.25% of protein and 0.75% of starch. Thirty ounces is equal to 900 cubic centimeters. Four per cent fat means that there are 4 grams of fat in each 100 cubic centimeters of food. The baby is taking 900 cubic centimeters of food, that is, it is taking nine times the amount of fat in 100 cubic centimeters of food, or nine times 4 grams, which is 36 grams. The caloric value of 1 gram of fat is 9.3 calories. Thirty-six grams of fat will give thirty-six times 9.3 calories, which is equal to 334.8 calories.

The caloric value of sugar, starch and protein is the same, each gram yielding 4.1 calories.[1] The caloric value of these elements can, therefore, be calculated at the same time. There are 6 grams of sugar, 2.25 grams of protein and 0.75 grams of starch, or a total of 9 grams in each 100 cubic centimeters of the food. There are, therefore, nine times 9 grams, or 81 grams, in 900 cubic centimeters of food. One gram is equivalent to 4.1 calories.

[1] The caloric value of a gram of milk sugar is in reality 3.78 calories.

Eighty-one grams provide 81 x 4.1 calories or 332.1 calories. The sum of the 334.4 calories furnished by the fat and the 332.1 calories furnished by the sugar, starch and protein is 666.9 calories, which is, therefore, the caloric value of the mixture.

The caloric value of the food is of importance only in its relation to the weight of the baby. Suppose that the baby who has been taking the above food weighs eleven pounds. Dividing the number of calories in the food by the weight gives the number of calories which it gets per unit of weight. That is, 666.9 calories divided by eleven gives 60 calories, which is the number of calories which it is getting per pound of weight.

A kilogram is equal to two and two-tenths pounds. Eleven pounds is equal, therefore, to 5 kilograms. Dividing 666.9 calories by five gives the number of calories which the baby is getting per kilogram of body weight, that is, 133 calories.

A simple, but less accurate, method of calculating the caloric value of a modified milk mixture is that recommended by Fraley (Archives of Pediatrics, 1912, xxix, 123). Letting F = the percentage of fat, S the percentage of sugar and starch, P the percentage of protein and Q the total quantity of food, then

$$2\,F + P + S \times 1\tfrac{1}{4}\,Q = \text{calories.}$$

This formula always gives the caloric value a little lower than it really is. It gives, for example, 637 calories as the value of the food just calculated above, when the real value is 666.9 calories.

Still another method, which is also accurate, is that recommended by Bowditch (Jour. A. M. A., 1909, liii, 1265). The caloric value of a food is very easily calculated by this method by the use of a table.

The Method of Determining the Protein Content of Mixtures of Modified Milk.—It is very easy to determine the protein content of a food by using the same principle employed in estimating the caloric value. Suppose that a baby weighing fifteen pounds is taking forty-eight ounces of a food containing 2.50% of protein. Forty-eight ounces is equal to 1440 c. c. There are 2.5 grams of protein in each 100 c. c. of food, or 14.4 x 2.5 grams in the whole amount. 14.4 x 2.5 grams = 36 grams. The baby weighs fifteen pounds. It gets, therefore, 2.4 grams of protein per pound of body weight in this food. Fifteen pounds is 6.8 kilograms. Dividing 36 grams by 6.8 gives 5.3 grams, which is the amount of protein which the baby gets per kilogram of weight from this food.

The Pancreatization of Modified Milk.—Pancreatized milk prepared with "Peptogenic Milk Powder" is often given to in-

fants. The objection to the use of pancreatized milk prepared in this way is that, if the directions as to the preparation of the food are followed, it is a routine food and not susceptible of variation to meet the needs of the individual infant at the given time. It is far better to make a mixture to meet the indications in the given case and then to pancreatize it by the addition of one of the "peptonizing" powders or tablets. In this way the advantages of a food suited to the needs of the baby and of predigestion of the food are both retained.

The food may be heated at "blood heat," not over 115° F., for ten minutes and then brought quickly to a boil. The ferments are destroyed by the boiling and the food will, therefore, not become bitter. It is better to add a part of the contents of a "peptonizing" tube or part of a tablet to each feeding just before it is to be used. The feeding is then heated for from ten minutes to fifteen minutes at blood heat, or from 100° F. to 115° F., being allowed to drop to 100° F. toward the end of this time, and immediately given to the baby. The advantage of this method is that the ferments are still active when the food is ingested and will continue to act until the reaction of the stomach contents becomes acid. The contents of a "peptonizing" tube, or a "peptonizing" tablet, are usually intended for the pancreatization of a pint of milk. The proportion of milk in each feeding being known, it is a simple matter to calculate how much of the powder or tablet to add. "Peptonized milk" prepared by the so-called "cold process" is, of course, not predigested at all, because the pancreatic enzymes do not act in the cold. The only opportunity which they have to act, when milk is prepared by this process, is after they are taken into the stomach. Their action ceases, however, when the reaction of the stomach contents becomes acid.

PROPRIETARY FOODS

The first thing to be remembered when considering the proprietary foods is that there are only certain food elements, namely, fat, carbohydrates, protein and mineral matters. There can, therefore, be nothing in the proprietary foods except these elements. All of the elements are easy to procure and can be put into modified milk in any form and in any amount desired.

It is often said that a certain baby did not do well on modified milk but at once began to thrive when given a certain proprietary food. Such a statement is undoubtedly true. This does not show, however, that this proprietary food is better than modified

milk. It merely shows that the combination of the different food elements in this food was the one suitable for this baby. There was nothing in the proprietary food which could not have equally well been put in a modified milk. The difficulty with modified milk was that the person who prescribed it did not understand or know how to meet the indications in the given case. If he had, the baby would have thrived as well on modified milk as on the proprietary food. It is noteworthy in this connection that while much is said in praise of a given food when a baby does well on it, nothing is said about all the other proprietary foods upon which it did not do well.

A great objection to proprietary foods is that their use tends to develop slip-shod methods on the part of physicians. They get in the habit of choosing proprietary foods at random or of using some food constantly, because they have seen a number of babies thrive on it, instead of thinking for themselves and endeavoring to prescribe a milk modification to fit the needs of the individual baby at the given time. Another objection to the proprietary foods is that, being led by the advertisements of the manufacturers of these foods to believe that the artificial feeding of infants is a very simple matter, parents attempt to feed their own babies on such foods instead of employing a physician to prescribe the feeding. The results are often unfortunate, to say the least.

A still further objection to proprietary foods is their cost. It is a self-evident proposition that the people who buy the foods have to pay for the manufacture and advertising of the food, as well as a profit to the manufacturer and various middlemen, neither the manufacturer nor the middlemen being in business "for their health." This expense is unnecessary, because modifications of milk containing everything which is in these proprietary foods can be readily prepared from simple materials in the home. The composition of some of the proprietary foods in most common use in this country is given in the table on pages 230–231.

It is noteworthy that these proprietary foods can be divided into four main groups. I. The condensed milks, sweetened or unsweetened. II. The malted foods, in which the whole, or a considerable part, of the carbohydrates is in the form of maltose and the various dextrins. III. The foods in which there is a considerable proportion of starch in addition to the soluble carbohydrates. IV. The foods which are almost entirely composed of starch. The different groups are worthy of separate consideration.

I. The Condensed Milks.—Condensed milk is almost never given undiluted. The customary dilution is one part of con-

TABLE 47

Name of food	Percentages					Source of analysis
	Fat	Sugar	Protein	Starch	Ash	
Condensed Milk—Eagle Brand	9.61	54.94 { Cane........42.91 Milk........12.03	8.01		1.78	Own advertisement
Condensed Milk—St. Charles .	8.70	10.95 Milk	8.80		1.40	Jordan & Mott. Am. Jour. Public Hygiene, 1910, XX, 391.
Ramogen..................	16.50	34.65 { Cane ....20.91 Milk 13.74	7.00		1.50	Own advertisement.
Mammala..................	12.12	55.34 Milk	24.35		4.93	Mellin's Food Co.
Horlick's Malted Milk	8.78	67.95 { Milk...... } 49.15 Malt ..... } Dextrins 18.80	16.35		3.86	Own advertisement.
Mellin's Food..............	0.16	79.57 { Malt ....58.88 Dextrins 20.69	10.35		4.30	Own advertisement.
Mead's Dextri-Maltose, No. 1.		93.00 { Malt ....52.00 Dextrins 41.00			2.00	Own advertisement.[1]
Laibose...................	17.00	55.00 { Milk ....25.00 Malt ....25.00 Dextrins 5.00	18.00		4.00	Own analysis.
Allenbury's Foods, No. 1 Milk	18.60	66.55 { Milk........42.00 Malt ....14.00 Dextrins.....10.00	10.66		3.95	Own advertisements, except proportions of different sugars. These given approximately from analyses made by Mellin's Food Co.
No. 2 Milk	15.88	70.90 { Milk........36.00 Malt ....20.00 Dextrins 13.00	9.90		3.71	
No. 3 Malted	1.05	25.11 { Malt ....16.50 Dextrins 8.50	10.23	60.01	0.60	

[1] Proprietors state that this analysis is only approximate, that the percentages of maltose and dextrin vary from 1% to 2% and that many samples show traces of protein and fat. "No. 2" is the same as "No. 1," except that it does not contain the 2% of salt.

TABLE 47—*Continued*

Name of food	*Percentages*					*Source of analysis*
	Fat	*Sugar*	*Protein*	*Starch*	*Ash*	
Eskay's Albumenized Food ...	3.52	55.82 { Milk ....54.12; Dextrins.... 1.70 }	6.70	29.90	0.99	Own analysis.
Nestlé's Food...............	5.50	58.93 { Milk .... 6.57; Cane ....25.00; Malt ....., Dextrins .. } 27.36 }	14.34	15.39	2.03	Own advertisement.
Ridge's Food...............	0.26	7.80 Milk, largely	12.50	73.67	0.61	Own analysis.[1]
Benger's Food..............	0.92	3.34 Dextrins & Sugars	12.12	77.02	0.97	Own analysis.[2]
Imperial Granum............	1.04	1.80 { Dextrose.... 0.42; Dextrins.... 1.38 }	14.00	73.54	0.39	Holt. Diseases of Infancy & Childhood, 1911, p. 162.[3]
Wheat Flour...............	1.00		11.40	75.10[4]	0.50	Bulletin No. 28. U. S. Dept. of Agriculture.

[1] Proprietors wish to emphasize the fact that the directions call for boiling, which "gelatinizes the starch in the form of colloids."

[2] Proprietors wish to call attention to the fact that the food contains active amylolytic and tryptic ferments which, when the food is prepared according to the directions, "convert the starch into soluble sugars and modify the casein."

[3] Proprietors wish to direct attention to the fact that Imperial Granum is intended to be used with milk.

[4] Total carbohydrates.

densed milk to nine parts of water. This dilution gives a mixture, if Eagle Brand Condensed Milk is used, containing 0.96% of fat, 5.49% of sugar and 0.80% of protein. This analysis explains why a baby that has a disturbance of digestion from overfeeding will do well on condensed milk. It will do equally well on a modified fresh milk containing the same percentages. It is also evident, from this analysis, that a very large amount of this food must be taken to cover the caloric and protein needs of a baby. The relation between the carbohydrates and fat is not a proper one for the normal well infant and the protein is too low. The caloric value of the food is even lower, when the unsweetened condensed milks are used. Condensed milk is, moreover, not a uniformly sterile product, as is commonly supposed. Some specimens are sterile, but many are not. The bacterial content of some of them is as high as 10,000,000 per cubic centimeter.[1]

II. The Malted Foods.—Horlick's Malted Milk and Mellin's Food are examples of this class. The chief reasons that foods of this class agree with so many babies are that the carbohydrates are in the form of maltose and dextrins and that the dextrins, by their colloidal action, favor the digestion of protein. When mixed with water, the mixtures are deficient, in that the fat and protein content is too low. When mixed with milk or cream, the result is a modified milk with the sugar in the form of maltose and the dextrins. It is far better to modify the milk to fit the need of the individual infant than to use one of these foods, as all the advantages of these foods can be obtained and the disadvantages avoided by the use of one of the dextrin-maltose mixtures instead of milk sugar, or by the dextrinizing of a cereal gruel.

III. The Sugary and Starchy Foods.—Examples of the foods which contain considerable amounts of starch in addition to various combinations of the various sugars are Eskay's Albuminized Food, Nestlé's Food and "Allenburys" Food No. 3. The fat content of the foods of this class is, as a rule, almost infinitesimal. When diluted with water they amount to but little more than a starch and sugar mixture. When mixed with some form of milk they correspond to a modified milk prepared with a cereal diluent.

IV. The Starchy Foods.—Imperial Granum and Ridge's Food are striking examples of the starchy foods, or rather of the starch foods. The composition of these two foods is almost identical. The following comparison of the analyses of Imperial Granum and ordinary wheat flour is interesting and instructive. (Table 48)

[1] Jordan and Mott: American Journal of Public Hygiene, 1910, xx, 391.

TABLE 48

	Fat	*Sugar*	*Protein*	*Starch*	*Ash*
Imperial Granum[1]	1.04	1.80 {dextrose 0.42, dextrins 1.38}	14.00	73.54	0.39
Wheat flour[2]	1.00	0.00	11.40	75.10 (total carbohydrates)	0.50

It is evident that the sum of the sugars and starch in Imperial Granum is essentially the same as the total carbohydrate content of wheat flour. Heating wheat flour will change a small percentage of the starch into dextrin and dextrose. It would seem cheaper for people to bake their own flour than to pay someone else to do it for them, even if they do put it up in a box and give it another name.

THE FEEDING OF INFANTS AFTER WEANING AND DURING THE SECOND YEAR

The average baby that has done well, whether it has been fed on the breast or artificially, will be taking, when it is about ten months old, a mixture of whole milk and barley water. It will be taking five feedings at three-hour intervals, beginning at six in the morning and ending at six at night. If it has shown a tendency to constipation, it will probably be taking some orange juice.

It may be remarked here, parenthetically, that orange juice is not a necessary part of a baby's diet, as many people suppose. It is advisable to give it, if the food is pasteurized or boiled, in order to guard against the possible development of scurvy. It is also useful, if there is a tendency to constipation. It will, moreover, sometimes restore a failing appetite. In such cases, however, it is probable that the loss of appetite is an early symptom of scurvy. It is wiser to give it for definite indications than to use it as a routine measure, although it probably does no harm in most instances, even if it is not indicated. The best time to give orange juice is one hour before a feeding, when the stomach is comparatively empty. It is less likely to disturb the digestion when given at this time. It is rarely advisable to give more than two tablespoonfuls to a young

[1] Analysis given by Holt. Diseases of Infancy and Childhood, 1911, p. 162.
[2] Chemical Composition of American Food Materials. Atwater and Bryant. Bulletin No. 28, U. S. Department of Agriculture.

baby. The whole amount for the day should be given at one time. It may be diluted with water and sweetened with cane sugar if desired.

The simple cereals should be begun about this time. The most easily digestible are barley jelly, oat jelly and farina. The barley jelly is made from barley flour, the oat jelly from oat flour or oatmeal thoroughly cooked and strained. Two or three rounded tablespoonfuls of flour to a pint of water will make a jelly. It should be cooked at least an hour. When oatmeal is used it should be cooked at least four hours. All cereals which are given to infants and children must be thoroughly cooked. Even the simple ones should be cooked several hours, in spite of the fact that the directions on the package may state that fifteen to twenty minutes is sufficient. The most satisfactory way of cooking them is in a "fireless cooker."

In beginning to feed cereals, they should be given at the beginning of the 9 A. M. and 6 P. M. feedings. Some of the baby's mixture should be put on them, never cream or top milk. They should be salted, but no sugar should be used. If babies begin to eat cereals without sugar, they learn to like them in that way and, as they grow older, do not expect to have them or other foods smothered in sugar. The chances of the development of a sugar indigestion in the future are thus much diminished. It is well to begin with a level tablespoonful of cereal, increasing the amount as necessary.

It is usually wiser to wait a few weeks after beginning to give cereals, before giving beef juice or broth. The most satisfactory form of beef juice is the freshly prepared beef juice. This is made by half-broiling a piece of round steak. The steak should then be cut into small pieces and the juice squeezed out with a beef press or a lemon squeezer. Beef juice prepared in this way contains about 0.60% of fat and 2.90% of protein, with a considerable amount of extractive matters. Dish gravy, as it is called, is not the same thing. It contains a large amount of cooked fat and is often highly indigestible. The various manufactured beef juices, meat extracts and similar preparations are not as good as the expressed beef juice and should be used only when it is impossible to obtain fresh beef juice.[1] Beef juice may be given plain or diluted with water. It should be salted to taste. It is wiser to begin with one teaspoonful, gradually increasing the amount to six

[1] See Bull. No. 114, Bureau of Chemistry, U. S. Dept. of Agriculture, "Meat Extracts and Similar Preparations," and Jour. A. M. A., 1909, liii, 1754, "Meat and Beef Juices."

teaspoonfuls, or one ounce. Babies should never be given more than two ounces of beef juice, even in their second year. Beef juice is liable to disturb the digestion of some babies and not infrequently makes other babies nervous and sleepless. It is always well, therefore, to warn mothers of this possibility when beef juice is first given. The best time to give beef juice is at the beginning of the noon feeding.

Mutton broth and chicken broth must be very carefully prepared. The fat must be entirely skimmed off and the broth should be thick enough to form a jelly when cold. Two ounces should be given in the beginning and this amount increased to four ounces later. The broth should also be given at the beginning of the noon feeding, beef juice being given one day, broth the next, and so on. It must be remembered that the nutritive value of broth is practically nil. The broth serves merely as a vehicle for other food and as a stimulant to the appetite.

It is well to begin to give breadcrumbs and zwiebach in the broth and beef juice in the course of a few weeks. At the same time the baby may be given bread or zwiebach "in its hand" in order that it may learn how to eat.

It is usually possible to leave out the cereal diluent when the baby is a year old and give plain milk. In many instances, however, it is advisable to continue to give an ounce of barley jelly or oat jelly in each feeding until the baby is one and one-half years old. The variety of cereals may be increased by the addition of Cream of Wheat, Ralston and rice when the baby is a year old. At about fourteen months it may have milk toast and bread and milk. If desired, a part of the milk may be given in the form of junket. If the baby is constipated, prune juice and pulp and the inside of baked apples may be added at this time or even earlier. Plain white crackers, such as soda crackers, Uneeda Biscuits or pilot wafers may also be given, either plain or in the form of cracker toast.

It is wiser, in general, not to begin to give eggs until babies are about eighteen months old. Many infants are poisoned by eggs. It is always advisable, therefore, to begin eggs very cautiously. Eggs should be given at first either soft boiled for about two minutes, or coddled for about four minutes. If eggs do not disagree, the baby may be given an egg every other day, and by the time it is two years old, an egg daily. This may be given in the morning or at noon in place of the broth and beef juice. At one and one-half years, baked potato, plain boiled macaroni, rice and Wheat Germ may be given. Baked custard, plain blanc mange and plain

boiled tapioca may also be given as desserts, if desired. There is no objection at this time to putting butter on the bread.

This dietary is sufficient until the baby is nearly two years old, when meat may be begun. The most easily digestible forms of meat are the white meat of chicken, mutton and lamb chop and scraped beef. A reasonable dietary for a baby of two years is whole milk, butter, mutton broth, chicken broth, beef juice, soft boiled eggs, coddled eggs, dropped eggs, white meat of chicken, lamb chop, mutton chop, scraped beef, French bread, stale bread, toasted bread, whole wheat bread, milk toast, zwiebach, plain white crackers, plain Educator crackers, barley jelly, oatmeal, Cream of Wheat, Wheat Germ, Ralston, farina, rice, baked potato, plain boiled macaroni, orange juice, baked apples, stewed prune pulp and juice, junket, baked custard, corn starch pudding, plain blanc mange, plain tapioca. It is not advisable, as a rule, to begin green vegetables until the baby is two and a half years old.

In most instances the hours of feeding are changed when the baby is from sixteen to eighteen months old. At that time the baby gets some milk when it wakes up in the morning. It has its breakfast between 8 and 8.30. It gets some more milk, or some milk with a piece of bread or a cracker, at 11 or 11.30, before its nap. It has its dinner when it wakes up from its nap at 1.30 or 2, and its supper at 5.30.

CHAPTER XIX

THE FEEDING OF PREMATURE INFANTS

All the functions of digestion of premature infants are feeble. In a general way, the younger the baby, the feebler are the digestive powers. Little is known positively as to the absolute or relative strength of the various digestive ferments in the premature. It is probable, however, that the tolerance for sugar is greater than that for fat and protein. The amylolitic function may be present at birth, but is relatively undeveloped and should not be called upon. It is presumable that the metabolic processes are less active in the premature than in the full-term baby and that the utilization of the food ingested is, therefore, less complete. There is, however, no proof of this supposition. It is a well-known fact that small bodies have a greater surface area in proportion to their mass than have large bodies. The loss of heat is, therefore, relatively greater in proportion to the weight in small than in large bodies. A premature infant would, therefore, be expected to require more nourishment in proportion to its weight than would the full-term infant. Another, and perhaps more important, reason why premature infants lose heat more rapidly than full-term infants is that they have very little fat tissue to act as a blanket to keep the heat in. They have, moreover, relatively more "active" tissue, *i. e.*, muscle, than full-term infants and it is apparently the active tissue which uses up energy and not the fat, which is inactive. The difficulties in the way of the successful feeding of premature infants are, therefore, obvious.

All the reasons which prove that human milk is the best food for the full-term infant are doubly applicable in the case of the premature infant. A premature infant should, therefore, always be given breast-milk, if it can possibly be obtained. None but the strongest infants or those but little premature should, however, be put to the breast. The vast majority of them are too feeble to nurse satisfactorily and are unable to bear the handling and exposure consequent on being put to the breast. Many a premature infant has had what few chances it had of survival destroyed in this way. The milk should be taken from the breast and fed to the baby. There is some difference of opinion as to whether it is

better for the newly-born premature baby to have colostrum or an established breast-milk. The evidence on the two sides is incomplete, and the question must be considered as still a mooted one. In most instances the baby will naturally get its own mother's milk, that is colostrum, while if it gets another woman's milk, it will usually be an established one. For practical purposes, either will do.

There is also considerable difference of opinion as to whether a premature baby should be fed within a few hours after birth, or whether it should not be fed for twelve hours or for twenty-four hours. Those who believe that it should be fed very soon argue that it needs nourishment at once, because of its prematurity and feebleness, while those who believe in waiting argue that Nature shows that a full-term baby should not have food for from twenty-four hours to forty-eight hours, since it does not provide food until this time, that the premature baby needs rest after the fatigue of labor more than does the full-term baby, and that it is even less able to digest food in the first few hours than the full-term baby. On the whole, it is probably best to begin to feed the premature infant when it is about twelve hours old.

There is also much difference of opinion as to the intervals at which premature babies should be fed. It used to be thought that, on account of the small amount taken at a feeding and the greater need for food, they should be fed every hour or every one and one-half hours. Such frequent feedings do not give the stomach a chance to empty itself, however, and do not give the baby a sufficient opportunity for continued sleep. Ten feedings at intervals of two hours during the day and of four hours during the night meet the indications better. The stomach then has time to empty itself and the baby is not disturbed too often. Czerny and Keller [1] have for a long time advocated four-hour intervals, and Litzenberg [2] has recently reported some extremely good results in a series of fifty cases fed at these intervals. His results show, if nothing more, that premature babies can thrive on these longer intervals. An additional advantage in these intervals is that if babies do thrive as well on them as on the shorter intervals, the care and attendance required are much less.

Caloric Needs.—The reason why the caloric needs of a premature baby would be expected to be greater than those of a full-term baby have already been mentioned. Experience has shown, moreover, that, on the average, premature babies that are thriving

[1] "Ernährung des gesunden Kindes," p. 685. Quoted by Litzenberg.

[2] Amer. Journal of Diseases of Children, 1912, iv, 391.

do take and require more calories per Kilo of body weight than do full-term babies.[1] The average quotient is, however, not as high as was formerly supposed. Most premature babies need about 120 calories per Kilo, but there are many exceptions. Some premature babies will thrive and gain on as little as 70 calories per Kilo. No attempt should be made to reach 120 calories per Kilo during the first few days. Thirty calories per Kilo is as much as it is wise to give in the first twenty-four hours of feeding. This amount should be gradually increased each day, watching carefully for symptoms of indigestion, and diminishing it if these appear. In most instances, 120 calories per Kilo can be given in about ten days. Very few are able to utilize more than 130 calories per Kilo. If this amount is exceeded, they are, in most instances, upset.

Character of Food.—The first food given should be breast-milk diluted with an equal amount of water or a 3% solution of milk sugar. The dilution should be diminished from day to day. In most instances undiluted breast-milk can be given in from four days to a week. If it is impossible to obtain breast-milk, the best substitute is modified cow's milk. It is very important to begin with very weak mixtures in order not to upset the digestion in the beginning. It is very easy to kill a premature baby or to disturb its digestion so much that a long time is required to remedy it by giving too strong a mixture in the beginning. On the other hand, it is very easy to strengthen the mixture, if the baby is not satisfied. It is never a mistake to give too weak a mixture; always a mistake to give a strong one. Whey mixtures are better than ordinary mixtures, because the protein is in a more easily digestible form and hence throws less work on the feeble digestive organs. The following mixtures are suitable ones:

Fat	1.00%
Milk sugar	4.00%
Total proteins	0.25%
Lime water	25% of the cream and milk in the mixture.

Fat	1.00%
Milk sugar	4.50 %
Total proteins	0.50%
Lime water	25% of the cream and milk in the mixture.

It is wiser to split the protein in these mixtures, making the whey protein and the casein the same. The mixture should be

[1] Morse: Amer. Jour. of Obstetrics, 1905, li, 589; Rott: Zeitschr. f. Kinderheilk, 1913, v, 134; Hess: Amer. Jour. Diseases of Children, 1911, ii, 302; Zahorsky: Baby Incubators, 1905.

gradually strengthened to cover the caloric needs, due attention being paid to the condition of the stools in deciding which element or elements to strengthen.

Amount of Food.—Whether the food is breast-milk or modified milk, it is better to begin by giving one drachm (5 c. c.) at a feeding. If the baby is not satisfied, it is very easy to gradually increase the amount. It should be increased every day or every few feedings, if necessary. No harm can be done in giving too little at first; irreparable harm may be done by giving too much.

Finally, always begin to feed premature babies with small amounts of a very weak food and increase the strength and amount at a feeding as rapidly as the individual baby's digestion will allow, bearing in mind that it is less dangerous to give too small amounts and too weak a food than to give too large amounts and too strong a food. If a premature baby's digestion is disturbed, it is not safe to give a cathartic freely and starve it. Like atrophic babies, they cannot bear starvation, but must be fed.

Water.—Premature babies, because of the high temperature and dryness of the air by which they are surrounded, need a considerable amount of water. It is estimated that the daily ingestion of liquid should be one-sixth of the body weight.

Methods of Feeding.—It is seldom advisable to put a premature baby to the breast, because it is usually too feeble to nurse well and because the handling and exposure consequent on being put to the breast overtax the vitality too severely. When the infant is strong enough to take food from a nipple, it should be fed from the bottle. Many babies are not strong enough to do this, however, and have to be fed in some other way. The most satisfactory way to feed such babies is with the Breck feeder. This consists essentially of a graduated glass tube, open at both ends. On the smaller end is a nipple about the size of the rubber of a medicine dropper. This is perforated and goes into the baby's mouth. On the other end is a large rubber finger-cot. By squeezing the finger-cot, milk is forced into the baby's mouth and efforts at sucking aided or induced. Some babies are too feeble to take food even in this way, and have to be fed with a medicine dropper. If a baby does not take its food well by any of these methods, there is no objection to feeding it with a tube. In fact, it often saps the baby's vitality less to be fed in this way than in any other. The passage of the tube seldom causes much strangling and vomiting, as the pharyngeal reflex is, in most instances, not fully developed. The tube should be passed through the mouth, not through the nose. A No. 9 or No. 10 catheter is suitable. It should be passed

in about fifteen centimeters, the distance from the gums to the cardia in full-term babies being seventeen centimeters ($6\frac{3}{4}$ inches) and less in the premature infant. If the baby is fed with the tube it is better not to give it more than eight feedings a day, fewer, if possible.

SECTION IV

DISEASES OF THE GASTROINTESTINAL CANAL

CHAPTER XX

SPASM OF THE PYLORUS

Spasm of the pylorus is more common in infancy than is hypertrophic stenosis. It is often a complication of stenosis and is not infrequently mistaken for it. In fact, it is probable that a very large majority of the cases of pyloric stenosis which have been reported as cured by medical treatment were not really cases of organic stenosis but of spasm.

ETIOLOGY

The etiology of spasm of the pylorus in infancy is very obscure. It apparently occurs most commonly in excitable and nervous infants, the offspring of neurotic parents. Some writers believe that the normal muscular hyperirritability at this age predisposes to pyloric spasm and that the mechanical irritation of the food or the chemical products of digestion thus directly or reflexly cause spasm when they would not in later life. Others believe that disturbance of the gastric digestion always precedes and causes the spasm. However this may be, it is certain that spasm of the pylorus occurs much more frequently in artificially-fed than in breast-fed babies. A hypersecretion of gastric juice has been found in some cases and hyperacidity of the gastric juice in others. The favorable results in many cases of treatment intended to neutralize hyperacidity make it seem probable that this is one of the causes, at least, of this condition. How large a proportion of the cases is due to this cause is uncertain.

SYMPTOMATOLOGY

In the first place, the baby is usually of the excitable, irritable and neurotic type. It is much more often artificially-fed than breast-fed. The first symptom is vomiting. It may appear imme-

diately after birth, but usually does not develop for several weeks and sometimes not until the baby is several months old. In the milder cases this is the only symptom. It is, however, often preceded and accompanied by evidences of gastric pain and distress. The vomiting is at times explosive and at others not. The amount of the vomitus does not ordinarily exceed the amount of food taken at the last meal. The vomitus shows, as a rule, little or no evidences of disturbance of the digestion. There is a tendency to constipation, but the stools show plainly that a considerable proportion of the food ingested passes through the pylorus into the intestine. The disturbance of nutrition is not extreme.

In the more severe cases there is visible peristalsis in addition to the symptoms already given as characteristic of the milder type. These symptoms are more marked than in the mild cases, the stools show less fecal residue and the disturbance of nutrition is much greater. In the most severe cases there is also a palpable tumor at the pylorus. This tumor is usually small in comparison with that felt in hypertrophic stenosis of the pylorus. It feels longer and thinner. In typical cases it can be felt to appear and disappear under the finger as the pylorus contracts and relaxes, in contradistinction to the tumor in hypertrophic stenosis which does not change.

Roentgenograms, taken after a bismuth meal, show very marked interference with the passage of the stomach contents into the duodenum. They seldom show, however, such complete and permanent obstruction at the pylorus as is commonly present in hypertrophic stenosis.

DIAGNOSIS

The differential diagnosis between spasm and hypertrophic stenosis of the pylorus has already been described in the discussion of the latter condition. The points of the greatest value in diagnosing spasm of the pylorus from indigestion with vomiting are the absence of evidences of indigestion in the vomitus, the explosive, projectile vomiting, the presence of visible peristalsis and of a palpable tumor, and the delay in the opening of the pylorus, shown in Roentgenograms taken after a bismuth meal. On habitual vomiting, the other condition with which spasm of the pylorus may be confused, the general condition of the baby is unaffected, the vomiting varies with the position and activity of the baby and is never projectile, the stools are sufficient in amount and fecal in character, there is no visible peristalsis and, of course, no palpable tumor.

PROGNOSIS

The prognosis is, in general, good. The symptoms persist for many weeks or months in the severe cases, however, even under the most careful treatment. Some of the most severe cases are not amenable to medical treatment and will die unless operated upon.

TREATMENT

The most important part of the treatment of pyloric spasm is regulation of the diet. The best food is good human milk. If this is vomited, it is well to remove a part of the cream and add lime water. The next best food is some modification of cow's milk. It is advisable to keep the percentage of fat low, because fat tends to delay the emptying of the stomach. A percentage of 0.50 is none too low in the beginning. It is also advisable to give as large a proportion as possible of the protein in the form of the whey proteins, because they are not coagulated by rennin and, therefore, easily pass the pylorus. Plain whey is very useful in some instances. All the measures which prevent the formation of large casein curds are applicable in this condition, in that they make the emptying of the stomach less difficult. Carbohydrates, which leave the stomach readily and quickly, can usually be given freely. Lactose is the best of the sugars in this condition. These general principles serve, of course, only as a basis for the preparation of the food, which must be varied to suit the individual baby.

Clinically, the addition of an alkali to the food is of considerable assistance in many of these cases, while in others it apparently does no good. It presumably does good by delaying the coagulation of the casein by rennin and thus favoring the passage of the liquid milk through the pylorus. It should be added in relation to the milk and cream in the mixture, not in relation to the total quantity or to the whey in the mixture. It is well to add lime water at first to the amount of fifty per cent of the milk and cream. If some other alkali is used, a corresponding amount should be given. Cowie [1] believes that the action of the alkali is dependent on the degree of the acidity of the gastric contents and the effect of the change of the reaction of the gastric contents on the pyloric reflex. If his explanation is correct, it is possible to exaggerate the condition by giving alkalis, and in any case the alkalis must be added very carefully, preferably on the basis of the findings obtained by the analysis of the gastric acidity.

There is much difference of opinion as to whether the food should

[1] American Journal of Diseases of Children, 1913, v, 225.

be given at short or long intervals and as to the quantity which should be given at a feeding. The most rational way of regulating the interval between feedings is to determine how long it takes the stomach to empty itself in the individual case and to make the intervals somewhat longer than this. In general, it is probably better to give small amounts at a feeding, although there are many exceptions to this rule.

Daily lavage with plain water or a weak solution of bicarbonate of soda is of assistance in most cases, although some authors think that it tends to keep up the spasm. Warm applications to the epigastrium for one-half an hour before and one-half an hour after feeding are sometimes of assistance. Flaxseed meal poultices are the most efficacious. Minute doses of some preparation of opium—*e. g.*, $\frac{1}{40}$ of a minim of the tincture—given a short time before feeding sometimes seem to diminish the spasm. Atropine and cocaine have also been used for the same purpose. It is also important to keep these babies very quiet, especially immediately after feeding.

Rosenhaupt [1] claims good results in this condition from rectal irrigations of salt solution, basing his treatment on Engel's statement that the cause of the trouble in gastrosuccorrhoea and on Benczur's experiments which show that in animals rectal injections of salt solution diminish the secretion of gastric juice. He obtained favorable results in all but one case, but does not state how many patients he treated. Rosenstern claims good results in four cases from the rectal instillation of from 250 c. c. to 400 c. c. of Ringer's solution daily. This method of treatment is, however, so new that it must be regarded as still *sub judice.*

Surgical intervention for the relief of pyloric spasm is seldom necessary. Experience has shown, however, that babies sometimes die of this condition under medical treatment. When, therefore, a baby is steadily going down hill under medical treatment, surgical intervention is indicated. An operation will relieve the symptoms and save the baby's life, just as it does in hypertrophic stenosis of the pylorus. The spasm will cease in time. When this happens and there is no longer any obstruction to the passage of the food through the pylorus, the food will then pass through the pylorus, the opening from the stomach into the bowel will close and the normal conditions be reëstablished.

[1] Deutsche med. Woch., 1909, xxxv, 1789.

CHAPTER XXI

HYPERTROPHIC STENOSIS OF THE PYLORUS

The pathological condition in this disease is an overgrowth of the circular muscular fibres of the pylorus. The longitudinal fibres are little, if at all, involved. The normal longitudinal folds of the mucous membrane lining the pylorus are hypertrophied. There is at times a slight increase in the connective tissue of the submucosa. The opening of the pylorus, which normally admits a No. 21 sound, French scale, is narrowed by the thickened muscle and the folds of mucous membrane until, in well-marked cases, it will not allow the passage of even a fine probe. In extreme cases it is impossible to force water through the pyloric opening. The tumor is usually about the size and shape of a dressed olive.

There is more or less hypertrophy of the muscles of the stomach wall in all cases. There is also almost always some enlargement of the stomach. This enlargement of the stomach may be considerable in advanced cases. The œsophagus is also sometimes somewhat dilated. The intestines are collapsed and empty. There are no evidences of inflammation and in most instances there is no catarrhal condition of the gastric mucosa. There is general wasting of all the organs and tissues as the result of starvation.

The muscular hypertrophy is sufficient after a few weeks, in the great majority of instances, to practically occlude the pyloric orifice and to almost or entirely prevent the passage of the gastric contents into the duodenum. It is probable that in other instances the hypertrophy is less marked and the narrowing of the lumen consequently less extreme. It is presumable that this hypertrophy is at the bottom of some of the cases of pyloric obstruction which develop in late childhood and adult life. It is possible that when the overgrowth is slight it may be neutralized by the growth of the parts with age. The facts that the conditions found at autopsy in one instance some months after gastroenterostomy for a complete obstruction were the same as at the time of the operation [1] and that Roentgenograms show that the food continues to pass through the new stoma for years after the operation indicate, how-

[1] Morse, Murphy and Wohlbach, Boston Medical and Surgical Journal, 1908, clviii, 480.

ever, that there is no diminution in the hypertrophy in those instances in which it is marked.

ETIOLOGY

The etiology of this condition is obscure and has given rise to much discussion. The weight of the evidence, however, is in favor of the view that it is a congenital abnormality rather than the result of muscular spasm, acting either before or after birth. There is no doubt, on the other hand, that in many instances in which the stenosis is not complete, the symptoms are exaggerated by spasm.

Hypertrophic stenosis of the pylorus occurs more frequently in boys than in girls. It is just as common in breast-fed babies as in the artificially-fed.

SYMPTOMATOLOGY

The first symptom is vomiting. It may begin in the first few days of life, but ordinarily does not appear before the beginning of the second week. It seldom develops after the first month. There is nothing characteristic about the vomiting in the beginning. It soon becomes forcible and explosive. The gastric contents may be shot out of the mouth to a distance of several feet. The vomiting usually occurs soon after the taking of food, but may occur at any time, sometimes not until just before the next feeding. Two, or even more feedings, are sometimes retained and expelled together. The whole of the stomach contents is usually vomited at one time. The vomiting is in most instances not accompanied by pain. The vomitus consists in the beginning simply of the food taken, which is more or less digested according to the interval which has elapsed between its ingestion and the vomiting. Later on it often contains mucus, but never, except in the rarest instances, bile. There is nothing characteristic about the reaction of the gastric contents. The baby is anxious to eat again immediately after it has vomited, unless it is temporarily exhausted by the process. In spite of the frequent vomiting, the tongue is clean and the breath sweet.

Constipation quickly develops, because so little of the food passes through the pylorus into the intestine that there is but little residue to be passed out of the bowels. The stools are small and, being composed of the same materials as the meconium, resemble it in appearance.

Loss of weight is a constant symptom. It is progressive and becomes more rapid as time goes on. It is due, of course, to the

lack of food and liquid as the result of the vomiting. The skin becomes dry, the face pinched and the baby soon shows all the evidences of starvation.

PHYSICAL EXAMINATION

The abdomen at first shows nothing abnormal on inspection. After a time, however, the epigastrium appears full when food is taken, and the rest of the abdomen sunken. When there is dilatation of the stomach, it may be recognized by inspection and palpation. Great care must be exercised in diagnosing dilatation of the stomach, however, because of the great variation in the normal position of this organ. Waves of peristalsis, running across the stomach from left to right, appear soon after the vomiting becomes marked. They occur only, of course, when the stomach has something in it. If they do not appear soon after food is taken, they can often be elicited by stroking the epigastrium, flicking it with a towel wet in cold water, or by the application of a piece of ice. They are usually about the size of half an egg and run very slowly across the epigastrium. Two, or even three, waves are sometimes visible at the same time.

A tumor can be felt in most instances. It is usually situated about midway between the tip of the ensiform and the navel and between one-half an inch and one inch to the right of the median line. This position is, however, not a constant one. The tumor is not infrequently under the edge of the liver. It ordinarily feels much like a dressed olive, both in size and shape. It does not vary in size. It may be mistaken for a large gland. If peristaltic waves are present, the tumor will often be found where they disappear. The tumor may be felt at any time. It is usually easier to find it when the stomach is empty than when it is full, but the opposite is sometimes the case. If there is any reason to suspect the presence of a pyloric tumor, the abdomen should always be examined with the stomach both full and empty. This is easily accomplished by having the baby fed or with the aid of a stomach-tube. The tumor is most easily felt during the relaxation after vomiting. Ether or chloroform should be used to produce relaxation, if necessary.

Under normal conditions, Roentgenograms of the stomach, taken immediately after a meal containing bismuth, show food passing through the pylorus into the duodenum. Roentgenograms taken at intervals afterwards show that the stomach is empty in most instances in from two to four hours. When there is stenosis of the

pylorus, Roentgenograms taken at once show nothing passing through the pylorus. Those taken afterwards show that little or nothing passes through the pylorus and show bismuth in the stomach for many hours, unless it has been vomited.

In many instances in which the muscular hypertrophy is not extreme, and presumably in most cases in the beginning, the narrowing of the pyloric canal which is caused by the mechanical obstruction of the tumor is increased by spasm of the muscle. It is the spasm of the muscle which accounts for the variation in the severity, or even intermittency, of the symptoms in many cases and for the sudden onset of severe symptoms in others. When a part of the obstruction is due to spasm, everything may be vomited for a time and then, when the spasm ceases, a considerable part of the food will be retained. The character of the stools will vary at the same time, resembling meconium when the spasm is marked and being fecal when it diminishes.

DIAGNOSIS

The diagnosis of a well-marked case of hypertrophic stenosis of the pylorus is very easy. The combination of vomiting, beginning within a few days or weeks after birth, increasing steadily in severity, becoming projectile in character and having no relation to the character of the food, marked constipation with meconium-like stools, visible gastric peristalsis and a palpable tumor, not varying in size, in the region of the pylorus, is pathognomonic. Although the tumor at the pylorus can almost always be found if carefully sought for under the proper conditions, a positive diagnosis of this condition is justifiable, if the other symptoms and signs are present, even if the tumor cannot be made out. The diagnosis should always be confirmed, however, if possible, by Roentgenograms taken after a bismuth meal.

The diagnosis between hypertrophic stenosis of the pylorus and spasm of the pylorus is, however, at times a very difficult one. The onset of the symptoms is the same in both, the vomiting is explosive in both and there is visible peristalsis in both. Constipation and loss of weight are common to both. There is sometimes a palpable tumor in spasm; the tumor is sometimes not palpable in hypertrophic stenosis. In spite of the similarity of the symptoms of the two diseases, there should be little difficulty in distinguishing the marked cases of hypertrophic stenosis from those of spasm, because the constipation is never so marked or persistent in spasm as in stenosis and because the tumor in spasm is small and cord-like, not

large and hard as in hypertrophic stenosis. Variation in the size of the tumor during examination is practically positive proof that the condition is one of spasm, not of hypertrophy. The difficulty in diagnosis comes between the severe cases of spasm and the mild cases of hypertrophic stenosis, because the difference in the symptomatology of the two diseases is entirely in the degree, not in the kind, of the symptoms.

It is impossible in many instances to make at first a positive diagnosis between these two conditions. If the baby is breast-fed, the chances are much in favor of hypertrophic stenosis, because spasm is very unusual in the breast-fed while hypertrophic stenosis is equally common in the breast-fed and in the artificially-fed. If the baby is artificially-fed, the chances are even, although if the feeding has been very irrational, spasm is a little the more probable. The absence of a palpable tumor is strong evidence against hypertrophic stenosis, but does not positively exclude it, because a good-sized tumor has sometimes been found at operation when none was felt before. It is never safe to conclude that there is no tumor, however, unless the abdomen has been examined with the stomach both full and empty, and with the abdominal walls relaxed, if necessary under an anesthetic. If no tumor is felt under these conditions, an almost positive diagnosis of spasm is justified. Examination of the gastric contents is of little or no assistance, because there are very few reliable data as to the chemistry of the gastric contents in these conditions and what few data there are are contradictory. An excessive hyperacidity perhaps counts a little, however, in favor of spasm. Dilatation of the stomach seldom develops in simple spasm of the pylorus and, if it does, is always slight. It develops in a certain proportion of the cases of hypertrophic stenosis, but is seldom extreme. The presence of dilatation is, therefore, in favor of hypertrophic stenosis and against spasm. Its absence does not count at all in favor of spasm. Dilatation of the stomach, unless extreme, is very difficult of demonstration in infancy. Too much importance must not be attached, therefore, to what are apparently slight degrees of dilatation. Rapid improvement under medical treatment and regulation of the diet is strong evidence in favor of spasm, but does not positively exclude a mild degree of hypertrophic stenosis complicated by spasm. The most important points in favor of spasm in doubtful cases are, therefore, the absence of a palpable tumor or, if a tumor is present, its cord-like feel, the presence of intermittent contraction and relaxation of the tumor, and rapid improvement under medical treatment and regulation of the diet.

Roentgenograms are of less value in the diagnosis between severe cases of spasm of the pylorus and mild cases of stenosis than between stenosis and other conditions, because there is obstruction at the pylorus and therefore delay both in the opening of the pylorus and in the emptying of the stomach in both cases.

When hypertrophic stenosis of the pylorus of slight or moderate degree is complicated by spasm of the pylorus, the variation in the severity of the symptoms and the temporary response to medical treatment and regulation of the diet are often most confusing. When there is hypertrophy there is, however, almost always, in spite of the variation in the symptoms, a progressive increase in their severity. The presence of a tumor which does not change in size or shape is conclusive proof that there is an organic stenosis, no matter how much the other symptoms may vary.

The diagnosis between hypertrophic stenosis of the pylorus and indigestion with vomiting is a comparatively simple one. Indigestion seldom occurs in the breast-fed, but develops, as a rule, after a longer or shorter period of bad artificial feeding. Vomiting is the most prominent symptom, occurs without any definite relation to the time of taking food, and is never explosive. The amount of the vomitus rarely exceeds that of the food taken at the last feeding and the vomitus usually shows evidence of disturbance of the gastric digestion. The stools often present the evidences of an associated intestinal indigestion, but constipation, as the result of the reduction in the amount of food retained, is not uncommon. The stools are, however, never of the starvation type, but show by their characteristics that food is passing from the stomach into the bowel. There is never any visible peristalsis and, of course, no tumor to be felt at the pylorus. Roentgenograms taken after a bismuth meal will settle the diagnosis at once in doubtful cases, because the food begins to leave the stomach immediately in indigestion, while nothing passes the pylorus for a long time when there is obstruction from a pyloric tumor.

Another condition which sometimes suggests hypertrophic stenosis of the pylorus is habitual vomiting. In this condition the baby without any other symptoms of indigestion vomits habitually. In spite of the vomiting, it nevertheless has stools normal in size and appearance and gains steadily in weight. These points are of themselves sufficient to rule out stenosis of the pylorus. Further points in which the symptomatology of this condition varies from that of stenosis are that the vomiting rarely occurs when the baby is quiet and that it varies with the amount of exertion and the position of the baby. The vomiting is never explosive and there is

no visible peristalsis or palpable tumor. The vomiting in this condition is sometimes due to an excessive amount of food, but more often, probably, to the lack of tone or imperfect closure of the cardiac orifice.

PROGNOSIS AND TREATMENT

The prognosis of hypertrophic stenosis of the pylorus, when the obstruction is marked and due wholly or chiefly to the muscular hypertrophy, is hopeless under medical treatment. Death will surely ensue in a few weeks as the result of starvation. These cases can be saved, however, by an operation, provided the operation is done at a time when the baby is able to stand the shock of the operation, which is a severe one. They should be operated upon as soon as the diagnosis is made. Every day of delay materially diminishes their chances of recovery. The preferable operation is a posterior gastroenterostomy. Another very good operation is the modified pyloroplasty recommended by Dr. Keefe.[1] Both operations require especial skill and should be performed only by surgeons who are in the habit of operating on infants or have had much experience in operating on small animals. The operative mortality is a low one when the operation is performed early and the surgeon is competent.

The medical treatment of these cases both before and after operation is of considerable importance. They should be given salt solution by enema or seepage, and if necessary subcutaneously, before the operation. The stomach should be washed out just before the operation. Salt solution should be given in the same ways after the operation. Feeding should be begun as soon as the baby has thoroughly recovered from the effects of the anesthetic. The best food is human milk, diluted at first with three parts of water, the strength being quickly increased. If this is not available, the next best thing is whey. This should be gradually strengthened by the addition of gravity cream to give 0.25% of fat, 0.50% of fat and 1.00% of fat. The regulation of the food from this time on is usually comparatively simple and along the general lines of infant feeding. It is advisable to begin to feed with one drachm (5 c. c.) every hour, increasing the amount and lengthening the interval between feedings as rapidly as possible. There is very little danger of overloading the stomach, because there is no obstacle to the passage of the food from the stomach into the intestine. The difficulty lies in the intestine, which has not been in the habit of receiving large amounts of food. If the intestine is contracted, as it

[1] Boston Med. and Surg. Journal, 1913, clxix, 318.

is in most cases which are operated on late in the disease, it is unable to take care of much food. If the operation is performed early, before contraction of the intestine has taken place, large amounts of food can generally be given.

The future development of babies successfully operated upon for hypertrophic stenosis of the pylorus is normal and their processes of digestion and absorption are not impaired.[1] The tumor does not diminish in size, the lumen of the pylorus is not restored and the food continues to pass through the gastroenterostomy opening, when the operation has been a gastroenterostomy.[2]

When the condition is one of partial stenosis complicated by spasm, the treatment is primarily that of spasm of the pylorus. The methods to be employed are described in the treatment of this condition. It is wiser, however, to operate in this condition also, unless the symptoms are quickly and almost entirely relieved. Unless this is done, the nutrition of the infant is certain to be materially impaired and its development retarded. There is but little reason to anticipate, moreover, that the organic obstruction will diminish in the future. It is also not improbable that a certain proportion of the cases of benign obstruction at the pylorus which develop in later childhood and early adult life are the result of mild degrees of infantile hypertrophic stenosis.

[1] Scudder: Surgery, Gynecology and Obstetrics, 1910, xi, 275; Talbot: Boston Medical and Surgical Journal, 1910, clxi, 782, and 1910, clxii, 490.

[2] Scudder: Surgery, Gynecology and Obstetrics, 1910, xi, 275; Morse: Murphy and Wohlbach: Boston Medical and Surgical Journal, 1908, clviii, 480; Koplik: American Journal Medical Sciences, 1908, cxxxvi, 1.

CHAPTER XXII

NERVOUS DISTURBANCES OF THE DIGESTIVE TRACT

Symptoms pointing to disturbance in the digestive tract develop not very infrequently as the result of causes or conditions acting directly on the nervous system. The symptoms referable to the digestive tract are due to disturbance of the functions of this tract as the result of abnormal influences transmitted to it from the unduly irritable or exhausted nervous centres. The most characteristic symptoms are those due to the disturbance of the mechanical functions of the stomach and intestines. When the symptoms are due to disturbance of the secretory functions of the digestive tract, they are indistinguishable from those due to disturbance of these functions from other causes. In fact, the condition is then an indigestion. Only those symptoms due to disturbance of the mechanical functions will, therefore, be described.

The most common of the causes acting through the nervous system are extremes of temperature, whether of heat or cold, more commonly of heat. Diarrhea is a more common result than vomiting. The vomitus consists simply of the contents of the stomach and shows no evidences of indigestion. The diarrhea is due to increased intestinal peristalsis. The intestinal contents are, in consequence, hurried through the bowels. The stools are, therefore, normal in every way, except that they are increased in number and diminished in consistency. Excitement and fear may have the same effect as extremes of temperature. The body temperature is not altered in these cases. There may, however, be a certain amount of abdominal discomfort and general constitutional depression.

It is conceivable that improper and indigestible food, acting simply as a foreign body may, through irritation of the stomach and intestines, reflexly cause vomiting and diarrhea without producing any disturbance of the digestive functions. If this occurs, it is, however, very uncommon. In such instances the vomitus and stools will contain the food which is the cause of the symptoms.

The primary cause of many of the more chronic disturbances of digestion is some error in the infant's care and routine, which results in over-excitement and exhaustion of the nervous system,

rather than improper food. Constant attention, noisy surroundings, lack of rest and sleep will often be found to be at the bottom of intractable cases of indigestion in infancy. No change in the diet will benefit them in any way, but they will begin to improve at once when the undue strain on the nervous system is removed.

TREATMENT

The first element in the treatment of these disturbances of the digestive tract due to causes acting through the nervous system is the removal of the cause. Recovery is usually prompt, when this is removed. It is also wise to omit one or two feedings and then to give the usual food weakened for one or two days. If the baby is on the breast, the duration of the nursings should be shortened and boiled water given before or during the nursing in order to dilute the milk. If the baby is taking an artificial food, it should be diluted with water. If the baby is on a mixed diet, the less easily digestible articles should be omitted.

If the cause of the trouble is indigestible food, it is best to give a laxative, such as milk of magnesia or phosphate of soda, to hurry it out of the bowels before it can set up a disturbance of the digestion. A laxative is not necessary, except when improper food is the cause.

If improper food is not the cause of the trouble and the baby is having a large number of loose stools, normal in other ways, it is allowable to diminish the excessive peristalsis by giving paregoric in doses of from five to twenty drops every two or four hours, according to the age of the child and the severity of the symptoms.

CHAPTER XXIII

DISTURBANCES OF DIGESTION

Disturbance of the digestion may be caused by an excess of an otherwise suitable food, by a too rich but otherwise well-balanced food and by foods containing an excessive amount of one or of several of the food elements. It may also be caused indirectly by other diseases or by any extraneous causes which weaken the general resistance or diminish the digestive powers. The disturbance may be either acute or chronic. The pathological changes in the gastroenteric tract are insignificant. In many instances there are no macroscopic changes beyond thinning of the intestinal wall. In others there is reddening of the surface and an excessive secretion of mucus, while in a few there is a desquamation of the superficial epithelium. The microscopic changes are slight and unimportant. In the more chronic cases there is a general wasting of all the tissues of the body and in both the acute and chronic cases there may be degenerative changes, frequently fatty, in the parenchymatous organs. The important changes are in the metabolic processes of the body. These are not recognizable pathologically. They are at present imperfectly understood. They vary according to which of the food elements is the cause of the indigestion.

Disturbances of the digestion are much less common in the breast-fed than in the artificially-fed. The symptoms are also, as a rule, less severe. All disturbances of the digestion, whatever their cause, have many symptoms in common. The other symptoms vary in accordance with the food element which is at the bottom of the disturbance. Disturbances of the digestion due to an excess of fat are likely to be more serious and more lasting than those due to the other food elements. Those due to an excess of sugar are more often acute and more often rapidly fatal. Those due to an excess of protein are apparently less frequent and less serious than those due to the other food elements. It must be remembered in this connection, however, that this apparent infrequency may be due to failure to recognize the symptoms and that the protein may really be at fault when the blame is attached to one of the other elements.

Simple disturbances of the digestion may be associated with

fermentation of the improperly digested intestinal contents as the result of bacterial activity. It is probable, in fact, that there is more or less fermentation in almost every case. When these fermentative processes are marked they often predominate the picture and the condition is then spoken of as indigestion with fermentation. The borderline between indigestion with bacterial fermentation and without it is, however, a very indefinite one. In many instances it is, therefore, impossible to determine in which class a given case belongs.

The following classification will be adopted in discussing the disturbances of digestion:

Indigestion.

1. Indigestion from an excess of food.
2. Indigestion from an excess of an individual food element.
   a. Fat
   b. Carbohydrates
   c. Protein
   d. Salts.
3. Indigestion with fermentation.

INDIGESTION FROM AN EXCESS OF FOOD

Breast-Milk.—Indigestion from an excessive amount of breast-milk is comparatively uncommon, because of the fact that Nature tends to accommodate the supply of milk to the demand and because, if an excessive amount is taken, the baby is very likely to regurgitate it before it has had time to cause any disturbance of the digestion. Indigestion from an excessively rich breast-milk is also somewhat uncommon.

The main symptoms of indigestion from an excessive amount of breast-milk or an excessively strong breast-milk are vomiting, an increased number of stools, failure to gain properly in weight, flatulence and colic. The babies are, as a rule, somewhat fussy and do not sleep well. The symptoms are seldom very marked. When the difficulty is in the strength of the milk, they are very likely to lose their appetites. There is nothing characteristic about the vomitus. The stools usually contain fat curds and more or less mucus.

The condition is seldom a serious one. It is usually easily corrected.

When there is too much milk, the duration of the nursing must be shortened. How much it should be shortened can usually be determined by observation of the baby's symptoms. More accu-

rate results can be obtained, however, by weighing the baby at intervals during the nursing and stopping the nursing when the desired amount has been obtained. The failure to empty the breasts will usually quickly bring about a diminution in the supply of milk. The mother should limit her ingestion of liquids until this happens.

When the breast-milk is excessively rich, the intervals between the nursings should be lengthened, as this procedure tends to diminish the amount of solids in the milk. The mother should eat more simple food and should take more exercise. Water should be given at the time of the nursing, to dilute the milk, until the strength of the milk has become normal. The amount of water to be given depends on the age of the baby and the strength of the milk. It may be given with a spoon or in a bottle before or during the nursing, or through a dropper introduced into the mouth beside the nipple during the nursing. It is almost never necessary to wean a baby because of an excessively strong breast-milk.

Artificial Food.—Indigestion from an artificial food, suitable in every way except that too much of it is given or that it is too strong in all its percentages, is more common than that from an excessive amount or strength of breast-milk, but infinitely less common than that from an artificial food containing an excessive amount of one or two of the food elements.

The symptoms of indigestion from an excessive amount of a suitable food or of too strong a food are loss of appetite, vomiting, an excessive number of stools, flatulence and colic, and failure to gain in, or loss of, weight. The babies are, as a rule, fussy and irritable and sleep poorly. The vomitus is not characteristic, but may show the evidences of disturbance of the digestion of any or all of the food elements. The stools are also not characteristic, and may also show evidences of the disturbance of the digestion of any or all of the food elements. Evidences of disturbance of the digestion of fat are, perhaps, the most common. If there is a considerable amount of vomiting, the stools may be constipated, because of the lack of sufficient food remnants to form the normal amount of feces.

The prognosis of indigestion due to too much of a good food or to an excessively rich, but otherwise suitable, food is usually good. The condition usually yields readily to proper treatment.

The treatment consists primarily in cutting down the amount of food or in weakening the food. It is advisable in most instances to weaken the food considerably more than enough to bring it to the strength which would be suitable for the average normal baby of

the given age. This is necessary, because the digestive processes have usually been so weakened by the excessive demands upon them that they are unequal to meet even the usual demands. After the digestive powers have recovered themselves, the food can gradually be strengthened. It is usually possible to straighten out these cases without a wet-nurse.

When the disturbance is an acute one from a temporary indiscretion the intestines should be emptied with castor oil or milk of magnesia and all food stopped for from twelve to twenty-four hours. When the disturbance is a chronic one, it is often advisable to begin treatment with a cathartic. It is not advisable to stop food, even for a time.

INDIGESTION FROM AN EXCESS OF FAT

Breast-Milk.—Indigestion from an excessive amount of fat in breast-milk is comparatively uncommon. The percentage of fat is seldom very high and, even if it is, babies are usually able to accommodate themselves to it.

The main symptoms of an excessive amount of fat in breast-milk are loss of appetite, vomiting and abnormal stools, with more or less flatulence and colic. Failure to gain in weight or a moderate loss of weight become manifest after a time. The symptoms are, however, seldom serious. There is usually nothing especially abnormal about the vomitus. It may, however, in the more severe cases, have the odor of butyric and other fatty acids. The stools contain many small, soft curds, and sometimes have an oily appearance. They are more acid than normal and may cause irritation of the buttocks. Soap stools are most unusual as the result of an excess of fat in breast-milk.

The disturbance caused by an excessive amount of fat in breast-milk is seldom a severe one, is not usually of long duration and is ordinarily easily corrected.

The amount of fat in the milk can sometimes be reduced by cutting down the fat in the mother's diet, provided she has been eating an excessive amount of it. In most instances, however, it will be found that she has been eating too much in general rather than too much fat. Cutting down her food as a whole, increasing the amount of the exercise which she takes and getting her out of doors more will usually promptly bring the amount of fat down to within normal limits. Shortening the duration of the nursings in order that the baby shall not entirely empty the breast is of some advantage, because the fore-milk contains less fat than the last

milk or "strippings." If the duration of the nursings is shortened, the intervals between the nursings must also be diminished in order that the baby may get enough food. Water may be given at the time of the nursing in order to diminish the percentage of fat by diluting the milk. This procedure has the disadvantage, however, of diminishing the percentage of the other food elements as well as that of the fat.

Artificial Food.—Indigestion is more often due to an excess of fat in artificial food than to an excess of any other single element. The results of a disturbance of the digestion from an excess of fat are, moreover, more far-reaching, more lasting and more difficult to correct than those due to any other element.

The symptoms are, in general, loss of appetite, flatulence and colic, vomiting, abnormal stools and failure to gain in weight or, more often, progressive loss of weight. The temperature is often elevated in acute disturbances of the digestion caused by fat, but is likely to be somewhat subnormal in the chronic disturbances.

The vomitus is acid in reaction and has a strongly acid odor. This odor is due to the presence of butyric and other fatty acids. It sometimes has a creamy appearance.

The most common abnormality in the stools is the presence of many small, soft curds. These are often accompanied by mucus. In other instances the stools have a gray, shiny appearance. When there is an excess of neutral fat, the stools may be of a creamy consistency and are often about the color of cream. In other instances they look like curdled milk. More often, especially in the chronic cases, the stools are gray, or grayish-yellow, large, hard and dry. They may sometimes be so dry as to be crumbly. The fat in these stools is in combination with calcium and magnesium in the form of soap, that is, these are the typical "soap stools." In other instances, the stools are watery, strongly acid, and cause marked irritation of the buttocks. When this happens, the fat is in combination with the alkaline salts, especially sodium.

When there is an acute disturbance of the digestion as the result of an excess of fat in the food, there is not infrequently a high fever. When there is diarrhea, as there often is in the acute disturbances, there is not only an excessive loss of fat in the stools, but also a very considerable loss of alkaline salts, especially sodium. A relative acidosis results, with an excess of ammonia in the urine. The symptoms of acid intoxication may then develop. The most characteristic of these are rapid and deep respiration, stupor or restlessness, and cherry-red lips.

When the disturbance of the digestion is a chronic one, there is

a continuous loss of magnesium and calcium in the stools and a consequent disturbance of the metabolism. This shows itself not only in a chronic disturbance of the nutrition but also by the development of the manifestations of rickets and of the symptoms of the spasmophilic diathesis. The manifestations of the disturbances of the nutrition as the result of the disturbance of the metabolism of the salts may become most marked, so that the babies come to present the characteristic picture of "marasmus" or "infantile atrophy."

The prognosis in disturbances of the digestion due to an excess of fat in an artificial food depends on whether the condition is acute or chronic. If the condition is an acute one, it varies with the severity of the symptoms, but is, in general, good. If the condition is a chronic one, the prognosis depends on the severity of the symptoms, the duration of the trouble and the degree of the disturbance of the nutrition. It is very grave in the more marked cases and recovery is always slow, even in the mild cases. It always takes a long time to reestablish a normal tolerance for fat. Relapses are frequent and of long duration. The least excess of fat in the food is almost certain to bring one on.

The treatment of disturbances of the digestion caused by an excessive amount of fat in an artificial food consists in diminishing the percentage of fat in the food. How much the percentage of fat is to be cut down depends on the severity and duration of the symptoms in the individual instance.

It is usually advisable to cut out the fat entirely in acute cases. In them, however, it can usually be cautiously added again in a few days. How rapidly it can be added can only be determined by observation of the symptoms and examination of the stools.

It is also advisable to cut out all of the fat in beginning the treatment of the severe, chronic cases of fat indigestion. In the less serious cases it is always wise to at once reduce the percentage of fat materially. Time is saved, recovery is hastened and tolerance established much more quickly, when the percentage of fat is immediately cut down below the limit of tolerance than when this point is reached by several insufficient reductions. It is never a mistake to reduce the percentage of fat more than is necessary. Time is always lost, if the reduction is insufficient. It is usually advisable to reduce the fat to at least 2% in the mild cases, to 1% in the more severe ones, and to cut it out entirely in the most serious. If the stools still show an excessive amount of fat after the initial reduction has been made, the percentage of fat must be reduced still farther. If they do not show any evidences of fat

indigestion, the percentage of fat should be cautiously increased. Not more than 0.25% should be added at a time. Several days should intervene between the changes. The stools should be examined after each change is made to determine if this amount of fat is well borne before the next change is made. It must never be forgotten that when the tolerance for fat has once been weakened, it is very difficult to reëstablish it and very easy to break it down again.

It must be remembered, on the other hand, that the continuous use of a food low in fat tends to weaken the power of digesting fat and, therefore, to lower the tolerance for fat. It must also be remembered that the caloric value of fat is very high and that, if the percentage of fat is very low, the caloric value of the food may be insufficient to meet the infant's caloric requirements. When the percentage of fat is much diminished, the percentages of the carbohydrates and protein must be increased in order to cover the caloric needs. This is sometimes very difficult to do without setting up a disturbance of the digestion through an excess of one of the other food elements, since the caloric value of fat is more than twice that of sugar, starch and protein.

Babies with an almost complete intolerance for the fat of cow's milk can often take the fat of human milk without difficulty. When, as is sometimes the case, it is impossible to feed babies having an intolerance for fat satisfactorily on artificial foods low in fat on account of the disturbance of the digestion caused by the other food elements, when the percentages of these elements are made high enough to cover the caloric needs, they should be given human milk. In some cases unfortunately, they are unable to tolerate the fat of human milk. In such instances skimmed human milk is the only resource.

INDIGESTION FROM AN EXCESS OF CARBOHYDRATES

Breast-Milk.—Indigestion from an excess of sugar in breast-milk is decidedly uncommon. The percentage of sugar is very seldom over seven and, if it is 1 or 2% higher, it almost never causes any disturbance.

The main symptoms of an excessive amount of sugar in breast-milk are flatulence and colic, vomiting and abnormal stools. The disturbance is seldom sufficient to cause any loss of weight. There is nothing especially characteristic about the vomitus. It may, however, sometimes have the odor of lactic or acetic acid. The stools are usually not especially characteristic. They are, however,

sometimes loose, light green in color, acid in reaction and irritating to the buttocks. They almost never, however, show the marked evidences of carbohydrate fermentation so common in the disturbances of digestion due to an excess of milk sugar in artificial foods.

The disturbance caused by an excessive amount of sugar in breast-milk is never a severe one and is not usually of long duration.

It is possible that, if the mother has been taking an excessively large amount of sugar, a reduction in the amount of sugar which she takes may result in a diminution in the percentage of sugar in the milk. If the amount of sugar ingested has been, however, within reasonable limits, cutting it down cannot be expected to have any effect on the percentage of sugar in the milk. In most instances it will be found that she has been eating too much in general rather than too much sugar. Cutting down the food as a whole, increasing the amount of exercise which she takes, and getting her out of doors more will ordinarily quickly bring down the percentage of sugar to within normal limits.

Artificial Food.—Indigestion from an excess of carbohydrates in an artificial food may be due to the excessive amount of either starch or sugar. The sugar at fault may be any one of the sugars commonly used in infant feeding, milk sugar, cane sugar or one of the dextrin-maltose combinations. The disturbances of the digestion caused by the various forms of carbohydrates have many symptoms in common. Each of them, however, also produces certain special symptoms or combinations of symptoms which are more or less characteristic.

Milk Sugar.—Milk sugar in an artificial food seldom causes any disturbance of the digestion, unless there is more than 7% of it in the mixture. Six per cent, or even 5% will, however, sometimes cause trouble in susceptible infants. It is never safe to give more than 7%. The disturbances caused by milk sugar may be either acute or chronic, but are more often acute. In a considerable proportion of the cases of indigestion resulting from an excess of milk sugar, a part of the symptoms are caused by the products of the fermentation of the sugar as the result of bacterial action. It is very difficult, and in many instances impossible, to determine how much of the symptoms are due to the disturbance of the digestion of the sugar and how much to the products of abnormal bacterial activity in the sugar.

The most prominent and characteristic symptom of a disturbance of the digestion from an excess of milk sugar is the passage of

loose, or watery, green, acid and irritating stools. They often contain more or less mucus. The odor is distinctly acid. In some instances the characteristic odors of lactic, acetic and succinic acids may be distinguished. The buttocks and genitals are often much excoriated. Vomiting is a less frequent, but is not an uncommon symptom. The vomitus is acid in reaction, and may also have the odor of lactic, acetic or succinic acid. It is usually watery. Flatulence and colic are common symptoms. Loss of weight is a constant and often a marked symptom in the acute cases; it is usually not very marked in the chronic disturbances. The temperature often rises rapidly and is not infrequently very high in the more severe acute disturbances of digestion resulting from an excess of milk sugar. It is seldom of long duration. It is doubtful, however, if the rise in temperature is directly due to the absorption of the sugar. It is probable that the explanation is not so simple. The temperature is but little, or not at all, elevated in the more chronic cases. The symptoms of intoxication may be very marked in the more severe acute cases. Among them may be mentioned restlessness and other manifestations of disturbance of the nervous system, marked prostration and disturbance of the respiratory rhythm.

The prognosis in the severe acute cases is grave. If the patients survive for forty-eight hours after the onset of the severe symptoms, they usually recover. Improvement is generally rapid after it once begins. The prognosis in the chronic cases is good as to life. It is usually some weeks or months, however, before the tolerance for milk sugar is thoroughly reëstablished. It is usually much easier, nevertheless, to overcome an intolerance for milk sugar than one for fat.

In the acute disturbances of the digestion from an excess of milk sugar, milk sugar must be eliminated as far as possible from the food. It must be remembered in this connection that whey contains between 4.5% and 5% of milk sugar. Whey and whey mixtures are, therefore, contraindicated in this condition. Fat is also usually not well tolerated. Small percentages of starch are ordinarily well borne. This is because the starch is broken down slowly and because its end-product, dextrose, is quickly absorbed. There is, therefore, never much sugar in the intestine at one time. The indications are, therefore, for mixtures containing but little fat and milk sugar and a considerable amount of protein, with or without the addition of starch. Mixtures containing from 0.50% to 1% of fat, 1% to 1.50% of milk sugar and 1% to 2% or even 2.50% of protein, with from 0.50% to 0.75% of starch are suitable ones.

Mixtures of skimmed milk with a cereal diluent, in various proportions, also meet these indications. It is usually somewhat difficult to cover the caloric needs of the infants with mixtures of this general character. It is therefore advisable, after a few days, to add one of the dextrin-maltose combinations to the mixture, in order to bring up its caloric value. It is usually possible to return after a short time to milk sugar. Eiweissmilch sometimes works very well in these cases. So also do mixtures prepared with precipitated casein, because in this way high percentages of protein can be given in combination with very low percentages of milk sugar.

Human milk is contraindicated in these cases, because of the high percentage of milk sugar which it contains. It is usually well borne, however, after the acute symptoms have subsided and in convalescence is, as always, the best food.

In the more chronic disturbances of digestion due to an excess of milk sugar, it is advisable to at once cut out all the milk sugar which is being added to the food, thus reducing the percentage of milk sugar to that which is necessarily put into the food in the cream and milk. If the mixture is in other respects a suitable one, the percentages of the fat and protein may be left unchanged. It is often advisable, however, to increase the percentage of protein a little, in order to bring up the caloric value of the food. The percentage of fat may also be increased for the same reason, but this must be done cautiously, because there is very likely to be a diminution in the tolerance for fat when there is a disturbance in the digestion of milk sugar. If the caloric value of the food is still too low, it may be increased after a few days by the addition of one of the dextrin-maltose combinations. Starch may also be added to the amount of 0.50% or 0. 75%.

In mild cases it is often possible to gradually put back enough of the milk sugar, increasing it 0.50%, or even 1.00%, at a time, to cover the caloric needs without causing a recurrence of the symptoms. In such instances it is not necessary to fall back on the dextrin-maltose preparations or starch. It is advisable to replace the dextrin-maltose preparations by milk sugar as soon as this is possible.

Whey and whey mixtures are contraindicated in these cases, because of the high percentage of milk sugar in whey. Eiweissmilch or mixtures prepared with precipitated casein are often useful in these cases, because a high percentage of protein may be given in this way in combination with a very low percentage of milk sugar. One of the dextrin-maltose preparations of starch may be added to these mixtures, if desired.

Cane Sugar.—The symptoms of disturbance of the digestion, whether acute or chronic, from an excess of cane sugar in the food are essentially the same as those from an excess of milk sugar. Extreme elevations of the temperature in acute disturbances are, however, somewhat less common. Babies that get a large amount of cane sugar in their food not infrequently show evidences of disturbance of the nutrition for some time before the appearance of the symptoms of disturbance of the digestion. They become fat, flabby and pale and their resistance to infection and disease is materially diminished.

The prognosis in disturbances of the digestion due to an excessive amount of cane sugar is essentially the same as that in the disturbances due to milk sugar. It is not quite as good in the chronic cases, however, because of the greater disturbance of the nutrition produced by the long-continued use of large amounts of cane sugar.

The treatment of disturbances of the digestion due to an excessive amount of cane sugar is along the same lines as when the disturbance is caused by milk sugar. The cane sugar should be at once cut out entirely, the percentage of sugar in the food thus being reduced to that of the milk sugar which is contained in the cream and milk in the mixture. After the symptoms of disturbance have ceased the percentage of sugar can then be gradually increased by the addition of milk sugar. If the symptoms recur when milk sugar is added to the mixture, one of the dextrin-maltose preparations can be substituted for it. Starch may also be added in order to increase the caloric value of the food.

Dextrin-Maltose Preparations.—The symptoms of disturbance of the digestion from an excess of one of the dextrin-maltose preparations are similar to those caused by the other sugars. The odor of the vomitus is acid, as in the case of the other sugars, but this odor is somewhat different, probably because of the presence in many instances of butyric acid. Flatulence and colic are usually more marked than when the disturbance is caused by the other sugars. The stools are usually loose or watery, and dark-brown in color, but are sometimes green. The odor is usually a peculiarly acrid one. Sometimes, however, it is that of butyric acid. The stools are strongly acid in reaction and cause very marked irritation of the buttocks, thighs and genitals. The elevation of the temperature in acute cases due to an excess of the dextrin-maltose preparations is usually less than when they are due to the other sugars.

The prognosis in the disturbances of the digestion caused by the dextrin-maltose preparations is somewhat better than in those

brought on by the other sugars. The acute disturbances are usually rather less severe and both the acute and chronic disturbances are somewhat more amenable to treatment.

The treatment of the disturbances of the digestion caused by an excess of the dextrin-maltose preparations is along the same lines as when the trouble is due to the other sugars. It consists primarily in the immediate withdrawal of the preparation. After one or two days the preparation may be cautiously added again or, as is usually better, milk sugar substituted for it. When an intolerance for sugar in general has been established, the caloric value of the food may be raised by increasing the percentage of protein in the food and adding starch. It must be remembered in this connection that the larger the proportion of maltose in these dextrin-maltose preparations, the greater, in general, is their laxative action. Sometimes, therefore, in the mild chronic disturbances of digestion, the substitution of another preparation containing a larger proportion of the dextrins will relieve the symptoms.

Starch.—The disturbances of digestion caused by foods composed entirely of starch are more often chronic than acute. Vomiting is a relatively uncommon symptom. Flatulence and colic are more common. The bowels are sometimes constipated; sometimes there is diarrhea. When the bowels are constipated the stools are small and brown. In some instances they are dry and crumbly. Constipation in these instances is the result of the insufficient amount of food, so much of the food being absorbed that there is but little left over to form feces. These stools have but little odor. Their reaction varies from acid to alkaline, according to whether the bulk of the stool is formed from starch remains or from the intestinal secretions.

When the stools are loose the color is brown and they have the appearance of mucus. In fact, they are often thought to contain mucus or to be composed entirely of mucus. The addition of some preparation of iodine to them will, however, turn them dark blue, showing that they are composed of unchanged starch and not of mucus. If the condition is not severe enough to give the starch test macroscopically, it will be plainly visible microscopically. These stools are acid in reaction. Their odor is acid, but only slightly so.

The disturbance of the nutrition caused by foods composed entirely of starch is far more serious than the disturbances of the digestion. This disturbance of the nutrition is due in part to the insufficient caloric value of these foods, but far more to their deficiency in protein and salts. Babies fed exclusively on starchy

foods may seem to thrive for a time in that they gain in weight, are of a fair color, and seem lively and well. Careful examination, even at this time, will show, however, that there is an exaggerated muscular tonicity. This is an early manifestation of the disturbance of nutrition. In a few weeks, however, they begin to lose in weight and color and their muscles become flabby. If the exclusively starchy diet is continued, they gradually take on all the characteristics of the starved, atrophic infant. Many of them die of intercurrent infections, however, before reaching this stage, the resistance to infection being especially lowered in the disturbances of nutrition caused by a diet consisting entirely of starch.

The prognosis in these cases of chronic disturbance of the digestion due to an exclusively starchy diet is always a grave one, partly because of the marked disturbance of the nutrition and partly because of the marked lowering of the resistance to infection induced by it. It is always many weeks, and often months, before the disturbance of the nutrition is entirely overcome. The prognosis in the acute cases is very good. They are usually very amenable to proper treatment.

The treatment in the acute cases is the immediate and complete withdrawal of the starchy food. A modified milk, in which the percentages are all low and in which the relation of the fat, milk sugar and protein to each other are similar to those in human milk, can usually be given at once. Examples of such mixtures are:

Fat........................1.00%
Milk Sugar.................4.00%
Protein....................0.75% and

Fat........................2.00%
Milk Sugar.................5.00%
Protein....................1.25%

Whey and whey mixtures are often useful under these conditions.

The treatment in the chronic cases is along the same lines. It is more difficult to fit the food to the digestive capacity in these cases, however, because the functions of the digestion and metabolism of fat and protein have usually been materially weakened by disuse and by the impairment of the nutrition. It is always advisable in these cases, therefore, to give human milk, if it can possibly be obtained.

The disturbance of the nutrition when the purely starchy foods are partially dextrinized is as great as when they are not. The

symptoms of disturbance of the digestion from starch are, however, diminished, although those from an excess of malt sugar may take their place. When the dextrin-maltose preparations or other sugars are added to the starchy foods their caloric value is increased and to this extent the disturbance of the nutrition is diminished. That due to the deficiency of protein and salts is, however, unaffected. The symptoms of disturbance of the digestion caused by these sugary and starchy foods are a combination of those due to an excess of starch and of those due to an excess of sugar. The symptoms caused by the excess of sugar usually predominate.

When starch is added in excess to a food of which milk forms the basis it causes but little disturbance of the nutrition and relatively little disturbance of the digestion. It seldom causes vomiting, but not infrequently causes flatulence and colic. It sometimes makes the stools harder and drier. It more often causes a looseness of the bowels. The stools are more acid than normal, have an acid odor and irritate the buttocks. The undigested starch may be visible in the movements and may be mistaken for mucus. If it is visible, it will turn dark blue when a preparation of iodine is added to the stool. If it is not visible macroscopically, it can be found in all cases microscopically. It is almost invariably associated with the presence of numerous iodophilic bacteria. These organisms are often found, moreover, before starch itself can be detected and, when found, they always suggest that a disturbance of the digestion from starch is imminent.

Disturbance of the digestion from starch is much less likely to occur, if ~~the starch is tho~~roughly cooked. It almost never develops unless there is 1% or more of starch in the mixture.

The prognosis of the disturbances of digestion caused by an excess of starch in mixtures the basis of which is milk is good. Recovery is ordinarily prompt when the cause is removed.

The treatment consists in cutting the starch entirely out of the food for a time. It can ordinarily be put back in reasonable amounts after a short time. The trouble will seldom recur, if the percentage of starch is not over 0.75%.

INDIGESTION FROM AN EXCESS OF PROTEIN

Breast-milk.—Indigestion from an excess of protein in human milk is much more common than from an excess of either fat or milk sugar. The protein is more likely to be excessive during the early part of lactation, before the equilibrium of the milk has been

established and the mother has resumed her normal life, than later. The excess of protein may be due to anxiety or nervousness on the part of the mother, or to either fatigue or lack of exercise, all of which increase the protein content of the milk. It is impossible to know in advance what percentage of protein will be an excess for the individual infant. Some babies are disturbed if the protein is more than 1.50%, while others can take 2.50% or even 3.00% without being disturbed in any way.

Vomiting, while it does occur, is a comparatively uncommon symptom of indigestion from an excess of protein in breast-milk. Flatulence and colic, on the other hand, are very common symptoms and are often very marked and very troublesome. There is almost invariably an increase in the number of the stools, which are either loose or watery. They are usually brownish-yellow instead of golden in color, but may be green. They not infrequently contain mucus and often fine, soft, fat curds. These may be due to a coincident fat indigestion, but are more often due to the increased peristalsis and consequent interference with absorption. The reaction is alkaline or feebly acid. The odor is not characteristic. It may be acid or a little foul. The stools do not ordinarily irritate the buttocks. The temperature may be slightly elevated, but ordinarily is not. In some instances, however, when the disturbance is an acute one from a sudden and marked increase in the percentage of protein, the temperature may be considerably elevated. The nutrition is not as much affected as would be expected from the amount of digestive disturbance. There is ordinarily not much loss of weight. Many babies continue to gain, although slowly, while occasionally a baby will gain rapidly in spite of much colic and many loose stools.

Disturbance of the digestion from an excess of protein in breast-milk is usually rapidly recovered from, if the cause of the excess can be removed. The results are seldom lasting. In rare instances, however, when there is a sudden and very marked increase in the percentage of protein, the babies may die within a few days. It is possible, however, that the cause of death in such cases may not be the excessive amount of protein but some unrecognizable chemical change in the milk.

The treatment of indigestion from an excess of protein in breast-milk consists primarily in regulation of the mother's diet and life in order to reduce the percentage of protein in the milk. When the percentage of protein is excessive, while the percentages of fat and sugar are within normal limits, it is probably impossible to diminish the percentage of protein alone by any change either in the

quantity or quality of the food. When the percentages of fat and sugar, as well as that of the protein, are high, it is possible to reduce them all simultaneously to a certain extent by cutting down the amount of food and increasing the amount of exercise which the mother takes. Increasing the length of the intervals between the nursings will also diminish the percentage of protein together with those of the other elements. The percentage of protein may also be diminished by giving the baby water at the time of the nursing. The percentages of fat and sugar are, however, also diminished to the same extent.

When the high percentage of protein is the result of inactivity on the part of the mother, it can be diminished by making her take more exercise. Exercise in the open air is preferable to that indoors. Care must be taken, however, that she does not take too much exercise and become fatigued, because fatigue increases the protein. If the excess of protein in the milk is due to fatigue or overwork, it can be diminished by resting the mother and keeping her more quiet.

When the high percentage of protein is due to nervousness, worry or anxiety, the remedy is obvious. The removal of the cause will at once result in a diminution in the percentage of protein. It is, however, unfortunately, seldom possible to modify a woman's natural temperament and frequently very difficult to remove causes of anxiety and worry.

Artificial Food.—A disturbance of the digestion is almost never due to an excess of protein in an artificial food, unless that food is cow's milk or some modification of cow's milk. When there is a disturbance of the digestion as the result of an excess of the protein in cow's milk, the excess is almost invariably of casein, not of whey protein.

Whey Protein.—When babies that are being fed on whey or on mixtures containing a high percentage of whey protein have a disturbance of the digestion, this disturbance is in the vast majority of instances due to the milk sugar and salts in the whey rather than to the whey protein itself. The symptoms are, therefore, those of an excess of milk sugar and of salts. It is probable, however, that in rare instances the whey proteins may cause a disturbance of the digestion. The chief symptom of such a disturbance of the digestion is the presence of an increased number of loose, watery stools. There may also be flatulence and colic. The stools may be normal in character, except for their diminished consistency, but are sometimes brownish and alkaline, with a musty odor.

The disturbance of the digestion from an excess of whey protein is usually not a severe one and ordinarily yields promptly to proper treatment.

The treatment of a disturbance of the digestion from an excess of whey protein consists in stopping the whey or diminishing the percentage of whey protein, and giving the necessary percentage of protein in the form of casein.

Casein.—The symptoms of disturbance of the digestion from an excess of casein are vomiting, flatulence and colic, abnormal stools and disturbance of the nutrition. The vomitus often contains very large curds. These curds may be fairly soft or tough and leathery. The vomitus ordinarily has but little odor. It may smell slightly acid, but is never strongly acid. Flatulence and colic are often quite severe. The chief abnormality in the stools is the presence of large, hard curds. The number of stools may or may not be increased. In many instances the stools are normal in character, except for the presence of the curds. In other instances, however, there may be an increased number of loose or watery stools, brownish in color and alkaline in reaction. The odor is musty. These stools at times contain an excess of mucus, but almost never curds. The disturbance of the nutrition from an excess of casein in the food is usually not very marked. There is ordinarily no fever, but in some instances it is moderately elevated. If the temperature is high, it is probably due to some other cause, such as an excess of salts.

The prognosis of disturbances of the digestion caused by an excess of casein is usually good. It is not a difficult matter, in most instances, to correct the disturbance by diminishing the percentage of casein or by the use of one of the numerous methods for preventing the formation of large casein curds.

When the disturbance of the digestion of protein results in the passage of watery, brown, musty stools, the protein must be cut entirely out of the diet for a time and some form of carbohydrate be given in its place. Any of the cereal waters, to which milk sugar or one of the dextrin-maltose preparations may be added, is suitable. Protein, best in the form of casein, must be added again as soon as possible, however, in order to prevent serious disturbance of the nutrition from the loss of body protein as the result of the lack of protein in the food.

When the disturbance of digestion shows itself by the vomiting of large curds, flatulence and colic, and the passage of large, hard curds in the stools, the object of the treatment is to prevent the formation of large curds in the stomach. If they are not formed

there, they will not be formed lower down. If the formation of large curds can be prevented, the casein will, in most instances cause no disturbance. The simplest way to prevent the formation of large casein curds is to diminish the percentage of casein in the milk mixture. When this plan is adopted, great care must be taken not to diminish the percentage of protein so much that the protein need of the baby is not covered.

A portion of the protein may be given in the form of whey protein. In this way the formation of large curds is prevented and yet the protein need of the baby can be covered. There are many methods for preventing the formation of large casein curds. These methods are very different, but the result obtained with all of them is the same. In some way or other the production of large casein curds is prevented or at least hindered. Some of these methods are boiling the milk, the addition of cereal diluents, the addition of lime water or other alkalis to the mixture, the addition of citrate of soda, and "peptonization" of the milk. Another way of preventing the formation of large casein curds is by using buttermilk. Still another way is by the use of precipitated casein in the milk mixtures, or in the form of Eiweissmilch. It is often very hard to decide which method to use in a given case. A careful study of the conditions in the case and a thorough comprehension of the way in which the formation of casein curds is prevented in each method will usually show, however, which one is the most suitable one under the circumstances. These methods are fully described on pages 202 to 205.

INDIGESTION FROM AN EXCESS OF SALTS

There is no doubt that the salts play a most important part in the metabolism of the other food elements and that the metabolic processes cannot progress normally unless the proper salts are present in the proper proportions. There is unquestionably a disturbance of the metabolism of the salts in all disturbances of nutrition in infancy. It is very difficult to determine, however, whether the disturbance of the nutrition in any given case is due primarily to a disturbance of the salt metabolism from an insufficiency or improper combination of the salts in the food or whether the disturbance of the salt metabolism is secondary to an insufficiency, excess, or improper combination of one or more of the other food elements and to the disturbance of the digestion caused by them.

There is no doubt, moreover, that the salts play an important

part in every digestive disturbance in infancy. It is probable, but not certain, that the salts may of themselves cause disturbance of the digestion independently of the other food elements. Very little is known as to the symptoms which an insufficiency or an excess of the salts as a whole in the food may cause. If the salts are cut out of a food, which is otherwise unchanged, the weight falls. When they are put back again, the weight rises. This variation in the weight is probably largely, but not entirely, due to variations in the retention of water. The sodium salts favor the retention of water. The salts of calcium diminish its retention to a moderate extent. It is also known that the withdrawal of salts from the food results in a lowering of the body temperature. An excess of calcium in the food also lowers the temperature. If a large amount of sodium chloride is given to a baby suffering from a disturbance of the digestion, there is usually a rise in the temperature. If there is no disturbance of the digestion, there is ordinarily no elevation of the temperature. Variations in the weight and temperature are, however, common to all disturbances of the digestion and do not, therefore, justify the diagnosis of indigestion as the result of some abnormality in the salts of the food. There being no symptoms peculiar to abnormalities in the salts of the foods, it is, therefore, impossible at present to make a diagnosis of indigestion from an excess or from an improper combination of the salts in the food. The condition may be suspected, but that is all.

— salt
— temp
NaCl. ↑ t

It being impossible to make a positive diagnosis of indigestion from an excess or an improper combination of the salts in the food, it is evidently impossible to make a definite prognosis or to lay down any rules for treatment.

Th~~e Medicinal Treatm~~ent of Disturbances of the Digestion in Infancy.—The treatment of the disturbances of digestion in infancy consists primarily in regulation of the diet. All other methods of treatment are relatively unimportant. They have their place, however, and cannot be dispensed with. They are especially useful for the relief of symptoms.

In the first place, the bowels should be thoroughly cleaned out in every acute disturbance of the digestion, whatever its cause, unless this disturbance is very slight. The most useful drug for this purpose is castor oil, because it is effective, acts quickly and causes less irritation of the bowels than calomel and strong salines.[1] The dose should be from one to three teaspoonfuls, according to the age of the baby and the effect desired. Babies do not, as a rule, object to the taste of castor oil. In fact, most babies like it.

[1] Abt. Archives of Pediatrics, 1909, xxvi, 836.

No attempt should be made, therefore, to disguise its taste. The stools produced by castor oil always contain mucus. Too much importance must not be attached, therefore, to the presence of mucus in the stools after a dose of castor oil.

If less vigorous catharsis is desired than that usually produced by castor oil, milk of magnesia may be used in its place. The dose is from one to three teaspoonfuls, according to the age of the baby and the effect desired. It may be given in the food, plain, or diluted with water.

Castor oil should be tried first, even if the baby is vomiting. It will often be retained when food is vomited. If it is vomited, calomel may then be tried. It is best given in doses of one-tenth of a grain combined with one grain of bicarbonate of soda, every half-hour, until one grain has been taken. It is advisable, but not necessary, to give one or two teaspoonfuls of the milk of magnesia three or four hours after the last dose of calomel. It should not be forgotten that calomel often gives the stools a peculiar green color that may be mistaken for that resulting from disturbances of the digestion in which the stools are excessively acid.

If the disturbance of the digestion is acute, severe and associated with considerable elevation of the temperature, it is also advisable to wash out the colon with salt solution or at least to give an enema of suds to clean out the bowel from below.

When the disturbance of the digestion is a chronic one, it is, as a rule, inadvisable to begin treatment with an initial catharsis. Catharsis is a weakening procedure and, when a baby is in a debilitated and feeble condition as the result of a long disturbance of the nutrition, is liable to do serious injury. When the disturbance of nutrition is extreme it may, in fact, take away the baby's last chance of recovery.

When babies with acute disturbances of digestion are vomiting, all food should be stopped. They may be given water to which bicarbonate of soda, in the proportion of one level teaspoonful to eight ounces of water, has been added, in teaspoonful doses, every ten to thirty minutes. If the vomiting is severe or persistent, the stomach should be washed out once or twice daily with a solution of bicarbonate of soda of the strength of one rounded teaspoonful to a pint of water.

It is not a difficult matter to wash out the stomach of a baby. There is usually no difficulty in introducing the catheter, even in the youngest baby. A soft rubber catheter, No. 16, American scale, or one a little smaller is used. The catheter should be attached by a short piece of glass tubing to a rubber tube attached to

a funnel. The baby should be well wrapped up and it and the nurse protected by a rubber apron or sheet. The baby should be held upright in the nurse's lap, facing forward and bending a little forward. The mouth can be held open by the forefinger of the left hand, around which a towel may be wrapped. The catheter, which is held in the right hand, is then pushed to the back of the throat and downward. It passes most easily when the baby gags. The distance from the gums or incisor teeth to the cardia during infancy is between seven and eight inches. The catheter should, therefore, not be introduced farther than this. It is very difficult to pass the catheter anywhere except into the esophagus. It is possible, however, to pass it through the larynx. Water should never be poured in, therefore, until the baby has cried clearly or food has come up through the tube. It is easier to start the siphonage if the tube is introduced full of water. The washing should be continued until the water returns clear.

It is rarely necessary or advisable to give an emetic to infants suffering from disturbances of the digestion. A teaspoonful of the wine of ipecac is the safest and best, if an emetic is necessary.

The best treatment for the flatulence and colic associated with disturbances of digestion is the removal of the cause. This is done by regulation of the diet. While the cause is being removed, the symptoms must, however, be relieved, if possible. It is advisable to try the simplest remedies first. These are hot applications to the abdomen and hot water by the mouth. If these measures are not effective, a quarter or a half of a soda mint tablet dissolved in an ounce of hot water may be tried, or from two to five drops of the essence of peppermint in the same amount of hot water. Five or ten drop doses of the elixir of catnip and fennel (Wyeth's) in one or two tablespoonfuls of hot water are sometimes useful. An enema of warm water will almost always stop the colic if other measures fail. It is very seldom necessary or advisable to use any form of alcohol or paregoric. Flatulence and colic are often due to the swallowing of air during the act of nursing, whether from the breast or bottle. The swallowed air tends to collect in the fundus. After the stomach is partially full the air cannot reach and be discharged through the cardiac orifice. If the baby is picked up from time to time during the nursing, held upright and its back patted, the air can escape and the flatulence and colic will be prevented.

There is little or no place for the so-called "digestants" in the treatment of disturbances of digestion in infancy. There is almost never a deficiency of either pepsin or hydrochloric acid in the gas-

tric secretion and rennin is always present. The pancreatic ferments cannot pass through the stomach without being destroyed. The only place for the digestive ferments in the treatment of these conditions is, therefore, in predigesting the foods before they are taken by the infant.

There is little or no absorption of fat through the skin, certainly not enough to have any appreciable effect on the nutrition. The only way in which inunctions of cod liver or other oils in chronic disturbances of nutrition can be of use, therefore, is through the stimulation of the peripheral circulation and muscular tone incident to the rubbing.

It is advisable to stop the food entirely for from twelve to forty-eight hours in all the acute disturbances of digestion from whatever cause. There is no danger in stopping the food, if the baby is given as much water as it would take of food. Babies can get along very well for a time without food, but they cannot get on without water. If they object to plain water, they will usually take it gladly if it is sweetened with saccharin. There is no objection to giving it in the form of very weak tea, sweetened with saccharin, if the babies like it better in this way. The length of time during which food is withheld depends on the severity of the symptoms in the given case.

Great care must be exercised in stopping the food of babies suffering from chronic disturbances of the nutrition, even when there is an acute exacerbation of the symptoms. Such babies are in no condition to bear acute starvation on top of a chronic inanition. In fact, the complete withdrawal of food is very likely to kill them. It is much wiser, therefore, under these conditions, to weaken or change the food than to stop it entirely.

CHAPTER XXIV

INDIGESTION WITH FERMENTATION

The term, indigestion with fermentation, is used to distinguish a condition in which fermentation takes place in the intestines as the result of the abnormal growth and activity of microörganisms in the intestinal contents. The term fermentation is used here in its broad sense and includes all the changes which take place in the various food elements as the result of the action of microörganisms upon them. In some instances the microörganisms concerned are the normal inhabitants of the intestinal tract, in others they do not belong to the normal intestinal flora.

It is extremely difficult to draw a distinct line between simple indigestion and indigestion with fermentation on the one hand and between indigestion with fermentation and infectious diarrhea on the other. It is assumed in the first instance that there is no fermentation in simple indigestion. This assumption is, of course, not strictly true, because there is unquestionably a certain amount of fermentation under normal conditions and more in simple indigestion. In simple indigestion, however, the fermentation plays but a small part in either the pathology or symptomatology of the condition and none in the etiology. In indigestion with fermentation, however, fermentation plays the major rôle. Whether the abnormal bacterial activity develops secondarily as the result of disturbances of the normal processes of digestion or appears primarily as the result of the introduction of an excessive number of bacteria, whether or not they are members of the ordinary intestinal bacterial flora, into the intestine or as the result of a change in the normal relations of the bacteria to each other from a badly balanced diet, the symptoms are due in the main to the presence of the abnormal products of bacterial activity. It is assumed in the second instance that in indigestion with fermentation there are no pathological lesions in the intestinal wall and that no microorganisms pass from the intestines into the general circulation. These assumptions are also not strictly true, because there are, without doubt, some minor changes in the intestinal wall in severe cases of indigestion with fermentation and it is presumable that an occasional microörganism enters the blood stream. The

intestinal lesions are, however, never marked, in contradistinction to the severe lesions characteristic of infectious diarrhea. It is presumable, moreover, although not proven, that in infectious diarrhea microörganisms frequently pass into the circulation, perhaps in considerable numbers.

Etiology.—So little is known accurately as to the normal intestinal flora and as to the normal variations in the relation of the individual elements of this flora to each other as the result of changes in the relative proportions of the various food elements, that it is extremely difficult to draw any positive conclusions from the microscopic examination of the stools, not only as to what organism or organisms are causing the trouble in a given case, but also as to what organisms may in general cause excessive fermentative changes. Furthermore, it is by no means always safe to draw positive conclusions as to the intestinal bacteria from an examination of the fecal bacteria. There is a certain amount of fairly satisfactory evidence to show that butyric acid bacilli, the B. acidophilus, and the B. putrificus may cause abnormal fermentative changes in the intestinal contents. It is probable that under certain conditions the colon bacillus may also be the cause of abnormal fermentative processes. The unrestrained and excessive activity of the normal lactic acid forming organisms of the intestinal flora may also result in an excessive acid fermentation sufficient to cause definite and severe symptoms. The B. perfringens, described by Tissier [1] has been proved more positively than any other organism to be the cause of fermentative diarrhea.

Pathology.—The pathological changes in the intestine in indigestion with fermentation are comparatively slight. In most instances there is presumably nothing more than an injection of the mucous membrane, while in the most severe cases the process does not progress beyond that of a mild catarrhal inflammation.

In the more severe cases of indigestion with fermentation there are more or less marked degenerative changes in the parenchymatous organs, especially in the liver and kidneys. True inflammation of the kidneys is, however, uncommon. Secondary infection of other organs, such as the middle ears and lungs, as the result of the general weakened resistance, are not uncommon in the serious cases.

Symptomatology.—Indigestion with fermentation is more often acute than chronic. When it is acute, there is in most instances some elevation of the temperature. The height of the temperature depends presumably on the amount of toxic absorption. In the

[1] Annales de l'Institut Pasteur, 1905, xix, 273.

most severe cases it may be as high as 104° F. or 105° F., or even higher. Such high temperatures do not, however, usually last more than three or four days, although the temperature may be moderately elevated for some days longer. The temperature is ordinarily but little, if at all, elevated in the chronic cases.

The appetite is usually impaired. Vomiting is unusual, and there is nothing characteristic about it, when it does occur. There is usually more or less abdominal discomfort, and the abdomen is not infrequently distended. There is, of course, always more or less loss of weight.

Diarrhea is a marked symptom in almost all cases of indigestion with fermentation. The character of the stools depends upon which of the food elements is being attacked by the microörganisms which are the cause of the trouble in the individual case. In the vast majority of instances indigestion with fermentation is due to organisms which produce fermentative changes in carbohydrates and to a less extent in fats. The stools are, therefore, usually green in color, strongly acid in reaction and odor, and irritating to the skin. They often contain a considerable amount of mucus, as the result of the irritation of the intestinal mucosa by the highly acid intestinal contents. They are often frothy and not infrequently contain many small, soft, fat curds. When the disease is caused by the abnormal activity of proteolytic organisms the stools are more often yellow or yellowish-brown than green. They are ordinarily alkaline in reaction and have a foul odor. They seldom contain curds, and mucus is a less prominent constituent. In one type of this class of cases the stools are rather characteristic, being frequent, small, watery, dark-brown, alkaline and with a peculiar musty odor.

There is almost always a moderate polynuclear leucocytosis in these cases, if they are at all severe. It is ordinarily not over 20,000, but in the severest cases may be much higher. In them, however, the toxemia may be so great that the system is overwhelmed. In such instances there is no leucocytosis.

The urine is usually diminished as the result of the loss of fluid through the bowels and the diminution in the intake. In the severe cases it not infrequently shows the evidences of acute degeneration of the kidneys. Acute inflammation of the kidneys is very unusual. The urine rarely contains sugar, unless the toxemia is extreme or very large amounts of sugar are being ingested.

In the most severe and fatal cases certain symptoms, such as uncontrollable vomiting, marked prostration and hyperpyrexia, are

likely to develop. In others there may be marked symptoms of irritation of the nervous system. These symptoms are in all probability due largely to toxic absorption from the intestines. They are more fully described in the chapter on Infectious Diarrhea, in which disease they also frequently develop.

Diagnosis.—The two conditions with which indigestion with fermentation may be confused are simple indigestion and infectious diarrhea. It is often very difficult to distinguish between simple indigestion and indigestion with fermentation, because of the fact that all but the mildest cases of simple indigestion are accompanied by a certain amount of fermentation in the intestinal contents as the result of bacterial activity in them. The border line between them is, therefore, a very indefinite one and must often be arbitrarily drawn. The manifestations of simple indigestion of the various food elements are, moreover, very similar to those of fermentation of these same elements as the result of abnormal bacterial action. This makes it still more difficult to draw the line. It has to be drawn principally on the relative severity of the symptoms in general and especially on the degree of the evidences of fermentation. When these predominate the picture, the diagnosis of indigestion with fermentation is justified. In general, moreover, the constitutional symptoms are more severe, the temperature higher, and the manifestations of toxemia more marked in indigestion with fermentation than in simple indigestion.

Mild or moderately severe cases of indigestion with fermentation are not likely to be confused with infectious diarrhea. The more severe cases, with high fever, marked evidences of toxic absorption and considerable amounts of mucus in the stools may, however, be mistaken for it. It is very often difficult to differentiate between them and it is not infrequently impossible to make a positive diagnosis. The most important single symptom in the diagnosis is probably the temperature curve, the elevation of temperature in severe cases of indigestion with fermentation being, as a rule, high and of short duration, while in infectious diarrhea, although not usually very high, it is constant and continuous. The stools show, in general, more evidences of fermentation in indigestion with fermentation than in infectious diarrhea, and never contain blood, as they do in infectious diarrhea. In a certain number of instances, however, a positive diagnosis can only be made by a bacteriological examination of the stools.

Prognosis.—The outlook is always grave in the cases which show marked evidences of toxic absorption. If they survive the first three or four days, however, they usually recover. Those

cases in which the stools are watery and dark-brown with a musty odor are also always serious. The cases in which the evidences of carbohydrate fermentation predominate are usually milder than the other types and yield fairly readily to rational treatment. A high temperature is not, of itself, of especially bad prognostic import. Neither are the presence of considerable amounts of mucus in the stools or of albumin and other evidences of degeneration of the kidneys in the urine. The cases which have become chronic are likely to drag along for a long time in spite of careful treatment.

Treatment.—It is advisable in all acute cases of indigestion with fermentation to at once thoroughly clean out the intestinal tract. The best drug for this purpose is castor oil. It works quickly, thoroughly and causes less irritation of the intestines than other cathartics. The dose should not be less than two teaspoonfuls. It should be given plain. If the castor oil is vomited, calomel should be given in its place. The usual dose is $\frac{1}{10}$ of a grain, combined with one grain of bicarbonate of soda, every half-hour until 1 or $1\frac{1}{2}$ grains have been given. It is wise to follow it with two or three teaspoonfuls of the milk of magnesia in two or three hours after the last dose. This treatment should be repeated, if the desired results are not obtained.

All food should be stopped for from twelve to twenty-four hours. It is not desirable, as a rule, to withhold food longer than this. It is necessary, however, to give water freely during this period, because, although a baby can bear temporary starvation, it cannot get along without water. At least as much water should be given as the baby would ordinarily take of liquid in the form of food in the given time. The water may be given either warm or cool, and may be sweetened with saccharin, if desired. There is no objection to giving it in the form of weak tea, sweetened with saccharin, if it is taken better in this way. It should be given through a tube, if the baby will not take it otherwise. It is not safe to continue the period of starvation longer than twenty-four hours when the microörganisms which are causing the trouble are of the proteolytic type, because the intestinal secretions are protein in nature and, therefore, provide a suitable culture medium for proteolytic bacteria. There is no objection to a longer period of starvation when the microörganisms are of the types which thrive on fats and carbohydrates, if it is for any reason indicated. Preliminary purgation and starvation are rarely advisable in chronic cases.

The object to be aimed at in the treatment of indigestion with fermentation is the destruction, or at least the inhibition of the activity, of the microörganisms which are the cause of the disease.

It is useless to attempt to do this by the administration of drugs by the mouth, because it is impossible to give any of the so-called intestinal antiseptics in large enough doses to have any effect on the pathogenic bacteria in the intestine without poisoning the baby. If they did have any action, it would be exerted, moreover, on the antagonistic as well as on the pathogenic bacteria. They would be likely, therefore, to do as much harm as good. It is possible that the salts of bismuth may diminish the intensity of the symptoms to a small extent. They do not have, however, any curative action. If they are used, they should be given in doses of from ten to twenty grains, every two hours. It is safer to use the subcarbonate or the milk of bismuth than the subnitrate, because of the danger of nitrite poisoning when the subnitrate is used. It is also useless to attempt to get rid of the pathogenic bacteria by irrigation of the bowels, because the fluid used in irrigation never reaches higher than the ileocæcal valve, if it reaches as far as that, while the chief seat of the trouble is in the small intestine.

It is possible in some instances to destroy the pathogenic micro-organisms, or at any rate to materially diminish their numbers and inhibit their activity, by the administration of antagonistic bacteria. This method has been proved to be effectual when the disturbance is due to the B. perfringens and organisms of the gas bacillus group. There is some evidence to show that it is of value when the trouble is caused by the B. acidophilus and proteolytic organisms. Tissier has shown that the B. bifidus has an antagonistic action on the B. perfringens. It is probable that it has a similar action on other pathogenic organisms. It is, however, anaërobic and, therefore, difficult of cultivation. Its use is, on this account, hardly practicable clinically. Lactic acid bacilli have, however, an antagonistic action on all the organisms mentioned. It is easy to obtain them in pure cultures and in any amounts desired. It is probable that the Bulgarian bacillus has some advantages over the other varieties. The lactic acid bacilli may be given in the form of broth cultures, in the form of buttermilk or in the form of modified milk ripened by them. They are effective when given in any of these ways. It seems most rational, however, to give them in the form of ripened modified milk, because when given in this way the food can also be modified to suit the needs of the individual infant. There is a certain advantage in the use of buttermilk and ripened modified milk over broth cultures of the lactic acid bacilli, in that they contain, in addition to the organisms, lactic acid which has been formed by them. This, in itself, has an antagonistic action on the growth of the pathogenic

organisms. When buttermilk and ripened modified milk are used in the treatment of indigestion with fermentation, they should not be pasteurized or boiled, because, if they are, the lactic acid organisms are killed and can, therefore, have no effect. It is self-evident that, when lactic acid bacilli are the cause of the fermentation, foods containing these organisms should not be given.

Another way by which the number of the organisms causing indigestion with fermentation can be diminished and their activity inhibited is by a change in the character of the infant's food. A change in the character of the food results in a change in the character of the intestinal contents, that is, in the medium in which the pathogenic organisms are growing. If these are of the types which thrive on a carbohydrate medium, the percentages of the carbohydrates should be diminished and that of the protein increased. The percentage of fat should also be diminished, because when there is an abnormal fermentation of the carbohydrates there is very likely to be a secondary fermentation of the fat. When the organisms are of the butyric acid forming type the percentage of fat should be much diminished, that of the carbohydrates diminished to a moderate degree and that of the protein increased. When the organisms are proteolytic, the percentage of protein should be diminished and that of the carbohydrates increased. The general principles to be followed as to the choice of carbohydrates in disturbances of the digestion which have been described in the chapter on indigestion are equally applicable in the treatment of indigestion with fermentation. It is evident that in certain instances it is possible to combine both methods of treatment.

Clinically, when the stools are loose, green, acid and irritating, the percentage of fat and carbohydrates in the food should be reduced and that of the protein raised. It is in cases of this type that "albumen milk" gives such satisfactory results. Beef juice, broths and albumen water may also be given. When a foreign protein is given under these conditions, there is always a possibility that it may pass through the intestinal wall unchanged and sensitize the baby. This is especially liable to happen with egg albumen. Albumen water should, therefore, always be used cautiously, if at all, in the treatment of the diarrheal diseases of infancy. Unless the fermentation is due to lactic acid bacilli, buttermilk and ripened modified milk mixtures, containing low percentages of fat and carbohydrates and a high percentage of protein, give better results than similar modifications unripened. If the fermentation is due to the lactic acid bacilli, the simple modifications give, of course, much more satisfactory results.

When the stools are brownish, alkaline and foul, the percentage of protein should be much reduced and that of the carbohydrates much increased. That of the fat should be kept low. Protein foods, such as beef juice, broth and albumen water should not be given. Buttermilk and ripened modified milk mixtures containing a low percentage of fat and protein and high percentages of carbohydrates usually give good results in these cases. So also does breast-milk.

Babies that are seriously ill with indigestion with fermentation are very likely to show one or more rather characteristic symptoms or groups of symptoms. One of these groups of symptoms almost invariably develops toward the end in fatal cases. These symptoms are:

(a) Excessive vomiting.
(b) Hyperpyrexia.
(c) Symptoms of irritation of the central nervous system.
(d) Prostration and collapse.

It is probable that these symptoms are chiefly manifestations of toxemia. It is presumable that the loss of water through the bowels also plays a part in their production. These symptoms also develop very frequently in infectious diarrhea. They and the treatment for them are fully described in the chapter on this disease. So also are the use of salt solution and stimulants in serious cases of diarrheal disease.

INTESTINAL TOXEMIA OF THE NEW-BORN

This condition, although not a very uncommon one, is often overlooked or mistaken for some other disease. Being in all probability due to bacterial infection of the retained meconium and the absorption of the toxic products formed by them in the meconium, it seems more rational to consider it under the head of indigestion with fermentation than elsewhere. There are no data as to the nature of the causative organisms or the pathological changes. The clinical picture is as follows.

Symptomatology.—A baby that was normal at birth and has continued to seem normal and to do well up to the second, third, fourth or even fifth day, becomes rather suddenly ill. He is likely to cry and moan considerably, although he is not infrequently unusually quiet. Attacks of cyanosis are a common and early symptom. Twitching of the extremities, slight general rigidity and retraction of the head come on in many instances, while

convulsions are not infrequent. The temperature is, as a rule, only moderately raised, but may be high. In the more severe cases the baby refuses to nurse. Vomiting is uncommon. In most instances there is no diarrhea; in fact, the tendency is to constipation. The symptoms develop in the majority of instances before the baby has ceased to pass meconium and it is very common to find that it has not passed as much as the average baby. If the stools are not composed of meconium, they are usually small in amount, loose, dark-brown and contain small, soft curds and mucus. They are often offensive. The abdomen may be distended, but usually is not. Loss of weight is generally rapid, the face becomes pinched and in all but the mildest cases it is evident that the baby is seriously ill. If the bowels are thoroughly cleaned out, all food stopped for a time and water given freely, recovery is usually rapid and complete. If the bowels are not cleaned out and food is continued, a fatal termination is not uncommon and recovery is, in any event, slow.

Etiology.—The most reasonable explanation as to the etiology of these cases is that a bacterial infection of the meconium, through either the mouth or anus, takes place within the first twenty-four or forty-eight hours after birth; that on account of the incomplete evacuation of the intestines the toxic products formed in the meconium as the result of this infection are absorbed into the circulation and that these toxic products cause the symptoms. Corroborative evidence in favor of this conception is that, as the meconium is made up of protein, the products of bacterial action in it must necessarily be putrefactive in character and, therefore, toxic. It is a well-known fact, moreover, that cyanosis may be enterogenous in origin. It may be asked why this symptom-complex is not merely a manifestation of septic infection, that is, of the entrance of bacteria into the circulation. It is impossible to state positively that this is not the case, because no blood cultures have been made in these patients. The early onset of the symptoms, the absence of any nidus of infection and the absence of other signs of sepsis, such as hemorrhages, marked jaundice and boils, make it improbable, while the rapid and complete recovery after the evacuation of the bowels seems sufficient to exclude it. It may also be asked why it is not simply a manifestation of starvation, analogous to the so-called "inanition fever." The answer is that it occurs both in babies that have not been fed and in those that have been, and that the withdrawal of food in connection with the evacuation of the bowels relieves it.

Diagnosis.—The diseases for which this condition is most

likely to be mistaken are cerebral hemorrhage as the result of injury at birth, meningitis, hemorrhagic disease of the new-born and septic infection of the new-born. The diagnosis from septic infection of the new-born is the most difficult. The symptoms appear earlier, as a rule, than do those of septic infection and the temperature is usually lower than in sepsis. There is no local nidus of infection, and marked general and local symptoms of infection, such as hemorrhages, deep jaundice and furuncles, are absent. There is a tendency to constipation and the stools are usually meconium-like in character. In many instances it is, however, impossible to make a positive diagnosis without the therapeutic test of free catharsis. Hemorrhagic disease of the new-born can be excluded on the absence of hemorrhages. Meningitis is extremely rare at this age and, when it occurs, it is a part of a general septic infection. There is almost invariably bulging of the anterior fontanelle in meningitis and usually when there is a cerebral hemorrhage. There are usually symptoms of focal irritation in hemorrhage and often blood in the nose and nasopharynx, while in both cerebral hemorrhage and meningitis there is likely to be spasm of the extremities and exaggeration of the knee-jerks. These latter symptoms, as well as other symptoms of cerebral irritation, may, however, also be present in intestinal toxemia. A lumbar puncture will settle the diagnosis at once in a doubtful case.

Prognosis.—The prognosis is a grave one in all but the mild cases, unless the condition is properly treated. If the bowels are thoroughly cleaned out at once and food stopped for a time, recovery is usually rapid.

Treatment.—The treatment consists in the administration of one or two teaspoonfuls of castor oil, the withdrawal of food for from twelve to twenty-four hours and the feeding of water or water sweetened with saccharin. It is also well to irrigate the bowels in the beginning. Bromide or stimulants, such as strychnia or caffein, may be used, if necessary. The best food, after the period of starvation, is human milk, plain or diluted, according to the individual baby's condition. Next to this, a mixture of cow's milk, low in fat, high in milk sugar and with a moderate amount of proteins, part of these preferably in the form of the whey proteins. A mixture containing 0.50% of fat, 5% of milk sugar, 0.50% of whey protein and 0.25% of casein would be a suitable one. It is important to give a high percentage of milk sugar in order to change the bacterial activity from the proteolytic to the fermentative type.

CHAPTER XXV

INFECTIOUS DIARRHEA

The border line between indigestion with fermentation and infectious diarrhea is necessarily a very indefinite one. The symptoms in severe cases of indigestion with fermentation differ but little from those in mild cases of infectious diarrhea. In both instances toxic substances, resulting from bacterial growth, are absorbed into the circulation and cause similar symptoms and pathological changes. In indigestion with fermentation, however, the bacteria do not enter the intestinal wall. The local lesions are, therefore, relatively insignificant. In infectious diarrhea, on the other hand, the bacteria do enter the intestinal wall and produce definite lesions of the wall. These lesions may or may not be severe. It is probable that bacteria very seldom pass through the intestinal wall and enter the circulation in indigestion with fermentation. It is probable that they often pass through the wall into the circulation in infectious diarrhea. In indigestion with fermentation the seat of bacterial activity is primarily and almost exclusively in the intestinal contents, while in infectious diarrhea it is primarily in the intestinal wall itself. In indigestion with fermentation bacteria are the secondary invaders of an abnormal intestinal content, while in infectious diarrhea they are the primary cause of the disease. These distinctions must not, however, be regarded as absolute. They are, nevertheless, definite enough to serve as a basis for classification and for treatment.

Etiology.—Infectious diarrhea is more common in hot weather than at other times of the year. The action of heat in the production of the disease is due mainly to the lowering of the general resistance to infection which it produces. It presumably also favors the development outside of the body of the microörganisms which are found in this disease. Microörganisms are, however, the primary cause of infectious diarrhea. The microörganisms which produce this disease are of several different types. They may be divided roughly into three main classes:

a. The dysentery bacillus in all its forms.
b. The gas bacillus and similar organisms.
c. Other organisms, of which the most important are streptococci, the colon bacillus and the bacillus pyocyaneus.

The symptoms produced by these different types of organisms are practically identical. It is usually impossible to determine from them which type of organism is causing the disturbance.

Pathology.—The pathological lesions of the intestine are very varied. There may be only a catarrhal inflammation. In other cases there are also superficial ulcerations. In others there is hyperplasia of the solitary follicles and Peyer's patches. In many instances ulceration takes the place of the hyperplasia of these structures. In still others a pseudo-membrane is formed, which may involve considerable areas. The pathological lesions are usually limited to the large intestine and the last two or three feet of the small intestine. They are ordinarily most marked in the large intestine. The severity of the symptoms does not always coincide with the severity of the intestinal lesions. In general, however, the symptoms are most marked in the cases in which the lesions are the most serious.

There is almost invariably a hyperplasia of the mesenteric lymph nodes. This almost never, however, goes on to suppuration. There are always more or less marked degenerative changes in the parenchymatous organs, especially in the liver and kidneys. True inflammation of the kidneys is, however, uncommon. Secondary infections of other organs, such as the middle ears and lungs, by other organisms as the result of the general weakened resistance, are not infrequent.

Symptomatology.—The onset of infectious diarrhea is usually acute. It may be preceded for a few days by symptoms of indigestion, but ordinarily there are no premonitory symptoms. The first symptom in most cases is diarrhea. The first stools are made up of fecal matter. Mucus and blood soon appear, however, and after a few hours or a day or two, the stools are composed almost entirely of mucus and blood. Pus is seldom visible macroscopically until several days after the onset and, in many instances, it is never seen. It can, however, almost always be found with the microscope. Membrane is also present in the severest cases. The mucus is often stained green or brown. The odor of the stools, when they are made up chiefly of mucus and blood, is very slight, but sometimes resembles that of wet hay. When the stools contain much pus or membrane, as the result of deep ulcerative or gangrenous processes in the intestine, the odor is putrefactive or gangrenous. The reaction of the stools is variable, but in most instances it is somewhat alkaline. The number of stools is large, twelve, twenty-four, or even more, in twenty-four hours. The stools are usually small, being often merely a stain of blood and

mucus. In a general way, the larger the number of stools, the smaller are the individual stools.

Pain in the abdomen and tenesmus are early, marked and severe symptoms. Tenesmus is especially troublesome and annoying and often keeps the baby restless and disturbed and prevents it from getting the proper amount of sleep. Prolapse of the rectum is not at all infrequent as the result of the straining.

Vomiting is a rather infrequent symptom and is seldom troublesome. The appetite is usually much impaired and there is not infrequently the greatest distaste for food of any sort.

The abdomen is sometimes distended, but in the vast majority of instances is much sunken. There is almost never any spasm of the abdominal muscles. There is sometimes tenderness over the course of the colon, but this is unusual. There is usually no enlargement of either the liver or of the spleen. Slight enlargement of the spleen is, however, not very uncommon. In some instances the liver becomes very large and this enlargement may develop very rapidly. The liver will sometimes enlarge enough in three or four days to reach well below the navel and to the anterior superior spine.

The temperature is always elevated in infectious diarrhea. It is usually only moderate, 100° F. to 102° F., but may be several degrees higher. It is more likely to be high in the beginning than later. The temperature is usually a fairly constant one without marked intermissions or remissions. It lasts throughout the active stage of the disease.

The symptoms are, however, not always so characteristic. The number of stools may be but little increased, mucus and blood may be scanty, or even wanting, and tenesmus absent. The symptoms may be, in fact, precisely like those of severe simple indigestion or of indigestion with fermentation. In such instances the continued temperature is the most suggestive symptom. The real condition can only be recognized in such instances, however, by a bacteriological examination of the stools.

The blood almost always shows a moderate polynuclear leucocytosis, usually somewhere in the neighborhood of 20,000. It may, however, be much higher. In the severest cases in which the toxemia is extreme and the system is unable to react, there may be no leucocytosis or even a leucopenia.

The urine is almost invariably diminished as the result of the loss of fluid through the bowels and the diminution in the intake. It not infrequently shows the evidences of acute degeneration of the kidneys. Acute inflammation of the kidneys is very unusual.

The urine rarely contains sugar unless the toxemia is extreme or very large amounts of sugar are being ingested.

In the most severe and fatal cases, certain symptoms, such as uncontrollable vomiting, marked prostration and hyperpyrexia, presumably due largely to toxic absorption, develop. These symptoms may also develop in the course of indigestion with fermentation. They will be discussed more in detail later and the treatment for them described at the same time.

It is impossible to determine from the symptoms what form of organism is the cause of the disease in the individual case. There is nothing about the stools which will aid in the differentiation except, in rare instances, the peculiar green color caused by the bacillus pyocyaneus. If the green color is produced by this organism, it will disappear when nitric acid is added to the stool. If it is due to bile, the characteristic color of Gmelin's test will appear when nitric acid is added. The microscopic examination of the stools is of little assistance in differentiating the various types unless the streptococcus is the cause, in which case it is usually present in large numbers and easily recognized. The presence or absence of the gas bacillus can be determined in from eighteen hours to twenty-four hours, or even less, by the following method.

This method is a simple one, which can be easily carried out by anyone. A small portion of the stool is added to a test tube of milk. The infected tube is then gradually brought to the boiling point of water in a water-bath and kept there for three minutes. In this way, all the bacteria not in the spore state are killed and the development of whatever spores may be present into vegetative cells is unrestrained by the presence of non-spore-forming organisms. The tube is then incubated at body temperature for from eighteen to twenty-four hours. When the gas bacillus is present, the casein is largely dissolved (usually at least 80%); the residual casein is somewhat pinkish in color and filled with holes; and the odor of the culture is much like that of rancid butter, as the result of the formation of butyric acid by the gas bacillus. Gram-stained preparations made from the milk show rather thick, short, Gram-positive bacilli, with slightly rounded ends. The fermentation is more easily observed if the milk, after being boiled, is put in a sterile fermentation tube. "Pseudo-reactions" may occur in which there is some liquefaction of the casein, but the shotted appearance of the residual casein is absent and there is no odor of butyric acid.[1] It must be remembered, however, in interpreting

[1] See Kendall and Smith: Boston Medical and Surgical Journal, 1910, Vol. clxiii, 578.

the results of this test, that the presence of a few gas bacilli does not necessarily prove that they are the cause of the disease. There is, unfortunately, no method for determining the presence or absence of dysentery bacilli that does not require special media and a fairly well equipped laboratory.

Diagnosis.—The only disease with which a typical case of infectious diarrhea is likely to be confused is intussusception. It is, however, usually not difficult to differentiate between these two conditions. Intussusception begins acutely with pain in the abdomen and evidences of shock, the stools of mucus and blood not appearing until later. The onset of infectious diarrhea is less acute, pain is usually not present, or, if so, it is slight, and there are no symptoms of shock, while the stools of mucus and blood appear almost at once. The stools contain no fecal matter in intussusception, while they usually contain some in infectious diarrhea. Fever is common to both diseases, but is usually higher in infectious diarrhea than in intussusception. The abdomen is almost always sunken in infectious diarrhea, but likely to be somewhat distended in intussusception. There is never any muscular spasm in infectious diarrhea, usually some in intussusception. There may be abdominal tenderness in both conditions. It is seldom marked in either, however, and is not of importance in the differential diagnosis. There is never a tumor in the abdomen or rectum in infectious diarrhea, while there often is one in intussusception. The absence of a tumor does not, however, rule out intussusception. Both conditions are usually, but not always, accompanied by a leucocytosis.

Simple indigestion and indigestion with fermentation are not likely to be mistaken for infectious diarrhea. Mild cases of infectious diarrhea in which the number of stools is not very large and in which there is no blood and relatively little mucus in the stools are very likely, on the other hand, to be mistaken for indigestion with fermentation. Fever, abdominal discomfort, anorexia, wasting and symptoms of toxic absorption are common to both conditions. These symptoms differ only in degree in the two diseases and may be more marked in indigestion with fermentation than in mild cases of infectious diarrhea. It is often very difficult to differentiate between them and it is not infrequently impossible to make a positive diagnosis. The most important single symptom in the diagnosis is probably the temperature curve, the elevation of temperature in indigestion with fermentation being ordinarily either very slight or high and of short duration, while in infectious diarrhea, although usually not very high, it is constant and con-

tinuous. In many instances a positive diagnosis can only be made by a bacteriological examination of the stools. An agglutination reaction is usually present in infectious diarrhea by the end of the first week or a little later when the disease is caused by the bacillus of dysentery. This reaction is, however, of but little practical importance.

When the temperature is high and the symptoms of cerebral irritation are marked and develop before the appearance of the characteristic stools, as they sometimes do, the disease may be mistaken for some form of meningitis. A careful analysis of the symptoms and physical signs will, however, usually make the diagnosis plain. A lumbar puncture will settle it at once.

Prognosis.—Infectious diarrhea in infancy is always a serious disease. The prognosis should always be a guarded one. It is impossible to know in the beginning what the result is to be. Death may occur in three or four days, but most often takes place during the second week of the disease. It may be delayed, however, for several weeks. Improvement usually begins, in the cases which recover, at the end of the first or during the second week. It may be delayed for several weeks. Recovery is usually slow and likely to be interrupted by relapses. In some instances the disease runs into a chronic form which may last for many weeks. Most of these cases eventually die, but some recover.

Symptoms which render the prognosis more serious are high fever, the presence of much blood in the stools and the appearance of symptoms of marked toxic absorption, such as persistent vomiting, marked restlessness and convulsions. The presence of albumin and other evidences of degeneration of the kidney in the urine are not of especially bad prognostic import.

Treatment.—The first thing to be done in infectious diarrhea is to thoroughly clean out the intestinal tract. The best drug for this purpose is castor oil. It works quickly, thoroughly and causes less irritation of the intestines than other cathartics. The dose should not be less than two teaspoonfuls and may be as much as two tablespoonfuls. It should be given plain. Castor oil should be tried first, even if the baby is vomiting, because it is often retained when food and water are vomited. If it is vomited, calomel may be given in its place. The usual dose is one-tenth of a grain, combined with one grain of bicarbonate of soda, every half hour until 1 or 1½ grains have been given. It is wise to follow it with two or three teaspoonfuls of the milk of magnesia in two or three hours after the last dose. The treatment should be repeated, if the desired results are not obtained. The lower bowel should

also be irrigated at once with physiological salt solution (approximately one teaspoonful of salt to a pint of water).

All food should be stopped for from twelve to twenty-four hours. It is not desirable, as a rule, to withhold food longer than this. It is necessary, however, to give water freely during this period, because, although a baby can bear temporary starvation, it cannot get along without water. At least as much water should be given as the baby would normally take of liquid in the form of food in the given time. The water may be given either warm or cool and may be sweetened with saccharin, if desired. There is no objection to giving it in the form of weak tea sweetened with saccharin, if it is taken better in this way. It should be given through a tube, if the baby will not take it otherwise.

The most important element in the treatment of infectious diarrhea is the diet. The character of the diet depends on the variety of microörganism which is causing the disease. These microörganisms can be divided, as far as the determination of the diet to be used is concerned, into two groups:

1. The various forms of the dysentery bacillus and the other organisms, except the gas bacillus, which cause the disease.
2. The gas bacillus and allied organisms.

The other organisms, although of many different varieties, are grouped with the dysentery bacilli, because as regards their growth and the production of toxic substances from protein and carbohydrate media, they behave in the same way.

The dysentery bacillus, the colon bacillus and the streptococcus belong to the class of facultative bacteria. This class of organisms can thrive upon either carbohydrate or protein media. They produce harmless products from carbohydrates and toxic substances from protein. They act upon and use up the carbohydrate material before they attack the protein, when both are present in the medium in which they are growing. The products of the breaking down of the carbohydrate material have, moreover, when produced in sufficient amounts, an inhibitory action on the development of dysentery bacilli and, to a less extent, of streptococci.

It is evident, therefore, that when infectious diarrhea is caused by bacteria of this type, the food should be largely carbohydrate in character. In this way the organisms are prevented from forming toxic substances and their growth is, to a certain extent, inhibited. The prolonged withdrawal of food is also contraindicated, because the intestinal contents are then made up entirely of the intestinal

secretions, which are protein in character. Some form of carbohydrate should, therefore, be given after a few hours. Sugar is preferable to starch, because it is much more easily utilized by bacteria. Lactose is preferable to the dextrin-maltose preparations, because it is more slowly broken down during the processes of digestion. Being less readily absorbed, it thus provides a carbohydrate medium in the intestine for a longer time than the dextrin-maltose combinations. It is probable, moreover, that a larger proportion of lactic acid is formed from milk sugar than from the other sugars, and lactic acid has an inhibitory action on the development of the dysentery bacillus. The lactose should be given in the form of a 5% or 7% solution in water. It is better to give it frequently in small amounts than in larger amounts at longer intervals, because in this way a continuous supply of lactose is brought to the intestines. The baby should be given at least as much of the sugar solution as it would take of food under normal conditions. Half as much more is usually advisable. There is little or no danger of producing sugar indigestion or glycosuria, if no more than this is given.

After twenty-four, forty-eight or seventy-two hours, as the case may be, it is wise to give the milk sugar in barley water. The barley water should contain from 0.75% to 1% of starch. The starch provides more nourishment and, being still more slowly broken up and absorbed, favors still further the prolonged continuance of a carbohydrate medium in the intestine.

It is necessary to add some protein to the food as soon as possible in order to neutralize the protein waste of the organism. It should be given as soon as there is evidence of improvement of the condition. Care must be taken not to give so much as to neutralize the action of the carbohydrates. It is usually safe to begin with 0.50%, increasing the amount 0.25% at a time as fast as possible up to about 1.50%. It may be given either in the form of whey protein or casein. If it is added in the form of casein, the mixture should be boiled in order to prevent the formation of casein curds. No fat should be given until convalescence is well established.

Irrigations of the colon with solutions of lactose or dextrose, while theoretically indicated, are of little practical value.

The microörganisms which cause the disease enter the intestinal wall and probably in many instances reach the mesenteric lymph nodes and perhaps the general circulation. The available supply of glycogen is quickly used up or greatly diminished in illness, especially when associated with total or partial starvation, and the conditions favorable for the development of toxic substances by

the bacteria which have left the intestines are thus provided. The introduction of dextrose into the circulation would, therefore, furnish a carbohydrate instead of a protein medium for the bacteria to grow in. The dextrose also provides an immediately utilizable supply of energy and spares the body protein. Dextrose infusions are, therefore, indicated in severe cases of infectious diarrhea of this type and in cases which are not yielding rapidly to treatment. The strength of the infusion should be 2.5% of dextrose in normal saline solution. Kahlbaum's is the only readily available pure dextrose. Three or four ounces of the solution may be given at a time and repeated every four to six hours. The administration of these infusions should be checked by urinalysis and must cease if sugar appears in the urine.

The gas bacillus and allied organisms grow rapidly in the intestinal tract when there is an excess of utilizable carbohydrate in the bowel and at the same time an insufficient number of those organisms which form lactic acid from carbohydrates to produce enough lactic acid to inhibit their growth, the gas bacillus being sensitive to lactic acid. The indications to be followed in the treatment of cases of infectious diarrhea caused by the gas bacillus are, therefore, to cut down the carbohydrates in the diet and to introduce acid producing bacteria into the intestines. These indications can be best met by the use of unheated buttermilk or, better, of mixtures containing no fat, 3% or 4% of milk sugar and from 1.50% to 2.50% of protein, ripened with lactic acid forming organisms. It is not possible to cut out the sugar entirely, because, if this is done, the lactic acid forming organisms will have nothing on which to grow. The lactic acid already present in the food exerts an immediately inhibitory action upon the gas bacillus, while the lactic acid forming organisms in it, by keeping up their production of lactic acid, continue this action. They also use up the available supply of carbohydrate and thus interfere with the growth of the gas bacillus. Lactic acid given by the mouth is much less effective, because it is rapidly broken down and absorbed and, therefore, does not have a continuous action. Pasteurized buttermilk, in which the lactic acid forming organisms are destroyed, is less valuable than raw buttermilk for the same reason.

Cutting down the carbohydrates in the diet and increasing the amount of protein in it is sufficient to relieve the condition in mild cases. The percentage of fat should also be kept low. Mixtures containing from 1% to 1.50% of fat and from 1.50% to 3% of protein, and with no more milk sugar than is necessarily added in the milk and cream to give the desired percentages of fat and pro-

tein, are suitable ones. It is well to boil them in order to prevent the formation of casein curds.

It is evident that the line of diet which is suitable for one type of infectious diarrhea is not only not suitable, but absolutely harmful, for the other, and vice versa. It is extremely important, therefore, not to make a mistake in the choice. It is unfortunately almost impossible to determine at once what form of microörganism is the cause in the individual case. The various methods to be used to get at the organism at fault have already been detailed. A point which is of some assistance in arriving at a tentative conclusion until these measures have been carried out is that in a given season the vast majority of the cases of infectious diarrhea are due to the same organism. If the prevailing organism is known the chances are, therefore, that this organism is also the cause in the given case. Another method of determining the cause, a method which is most unscientific but nevertheless often the only practicable one, is to give what seems to be the most rational diet and then observe the results. If the temperature begins to come down and the patient improves, it is almost certain that the organism causing the disease is of the type for which that form of dietetic treatment is indicated. If, on the other hand, the temperature remains elevated or rises and there is no improvement in the other symptoms, it is evident that the causative organism belongs to the other type and that the diet must be changed.

Irrigation of the bowels once or twice in the twenty-four hours is a useful procedure. The object of the irrigation is simply to cleanse the colon. It is impossible to use astringent solutions strong enough to have any appreciable action upon the intestinal wall, even if this was desirable, or antiseptic solutions strong enough to have any effect upon the pathogenic bacteria without running serious risk of poisoning the baby. The irrigating solution should, therefore, be some mild, unirritating solution, such as physiological salt solution or a 1% solution of boracic acid. The irrigation should be given with a soft rubber catheter, No. 25 French, passed as high as possible into the bowel, with the patient lying on the back and the hips elevated. The fluid is then allowed to run in from a bag hung not more than two feet above the level of the patient. It should be allowed to run in until the abdomen is slightly distended, then allowed to run out, and so on, until the wash water returns clear. The object of the irrigation being to cleanse the colon, enough liquid should be used to do this, whether it is much or little. Irrigation should seldom be done more than twice in the twenty-four hours. If it depresses or disturbs the

patient materially, it should be given up, as under these circumstances it does more harm than good.

In subacute or chronic cases, in which blood and pus persist in the stools after the temperature has dropped and the evidences of toxemia have disappeared, injections of nitrate of silver are sometimes useful and seem to hasten the healing of the bowel. They may be used in the acute stage, but, as a rule, do but little good at this time. The colon should first be irrigated with sterile water in order to cleanse it. Salt solution should not be used, because the sodium chloride forms with the silver nitrate an insoluble silver salt which is precipitated and the action of the silver solution is consequently diminished. After the bowel has been washed out, from six to sixteen ounces, according to the age of the baby, of a 2% or 3% solution of the nitrate of silver are allowed to run into the colon and the tube then withdrawn. No attempt should be made to have the fluid either retained or expelled. This procedure seldom causes any marked discomfort in babies. If it does, the silver solution may be washed out with salt solution or an opium suppository given. The injections should be repeated every day or every other day. If there is no evident improvement after three or four injections it is useless to continue them. The first stools passed after an injection usually contain more blood and considerable dirty gray material, consisting of slough from the ulcers, intestinal secretions and pus, discolored by the silver nitrate. In favorable cases, however, there is marked improvement in the character of the stools inside of twenty-four hours.

The various so-called intestinal antiseptics are of little or no value in the treatment of infectious diarrhea. It is impossible to give them in large enough doses to have any effect on the pathogenic bacteria in the intestines without poisoning the baby. If they did have any action, it would be exerted on the antagonistic as well as on the pathogenic bacteria. Moreover, the bacterial flora can be modified better by regulation of the diet than in any other way. In addition, it disturbs the patient to take them and interferes with the administration of food and water. The salts of bismuth are of little value during the acute stage, whether or not they are combined with sulphur. During the chronic stage they sometimes seem to diminish peristalsis and perhaps promote healing. When used, they should be given in doses of from ten to twenty grains every two hours. It is safer to use the subcarbonate or the milk of bismuth than the subnitrate, because of the danger of nitrite poisoning when the subnitrate is used.

There is no serum which is of any value in the treatment of infectious diarrhea.

Pain and tenesmus are often very troublesome symptoms. Injections of two ounces of starch solution of the strength of one drachm of starch to one ounce of water, to which are added from three to five drops of laudanum, will sometimes control the tenesmus. They are usually expelled, however, before they have had time to do any good. It is generally wiser, therefore, to give the opium by mouth, if it is necessary to use it at all. It must be remembered when giving opium that its action is to diminish peristalsis and that if the peristalsis is diminished enough to interfere with the free emptying of the bowels serious harm will be done. Only enough should be given to allay the tenesmus and prevent the frequent stools due to excessive peristalsis. The safest form of opium to use is paregoric. It may be given in doses of from five to twenty drops. Dover's powder, in doses of from one-eighth to one-half of a grain, may also be used. It is better to give small doses at short intervals than larger doses at longer intervals. The use of hot stupes or compresses to the abdomen will, however, often relieve the pain and tenesmus and render the use of opium unnecessary.

In some instances it is impossible to induce the infant to take a sufficient amount of water or, if it does take it or it is given through a tube, it is vomited. In such cases physiological salt solution should be given subcutaneously to make up the deficit. From four to six ounces may be given at a time and repeated as often as necessary. It is useless to give a second injection, however, before the first one is absorbed. Salt solution may also be given through the bowel by seepage. Considerable amounts can sometimes be introduced in this way, even when the baby is having many stools.

Stimulants are often necessary in infectious diarrhea in infancy, as in other acute diseases. There are no special rules to be followed in infectious diarrhea. Alcohol is of doubtful value. Strychnia is, in general, the most useful, while caffeine and camphor are the best quick stimulants. Strychnia may be given in doses of from 1/1000 to 1/200 of a grain. The dose of the citrate of caffeine by mouth for a baby is from one-eighth to one-half of a grain and of caffeine-sodium benzoate or salicylate subcutaneously about the same. Camphor may be given subcutaneously in oil in doses of one or two grains.

Special Symptoms.—Babies that are seriously ill with either indigestion with fermentation or infectious diarrhea are very likely to show one or more rather characteristic symptoms or

groups of symptoms. One of these groups of symptoms almost invariably develops toward the end in fatal cases. These symptoms are:

a. Excessive vomiting.
b. Hyperpyrexia.
c. Symptoms of irritation of the central nervous system.
d. Prostration and collapse.

It is probable that these symptoms are chiefly manifestations of toxemia. How much of the intoxication is due to the absorption of bacterial endotoxines and extracellular toxines, how much to the absorption of the products of bacterial fermentation in the intestinal contents, and how much to purely chemical disturbances of metabolism, it is impossible to state. It is presumable that the loss of water through the bowels also plays a part in their production.

If, when any of these symptoms appear, there is any doubt as to whether the bowels have been thoroughly emptied, it is advisable to repeat the initial catharsis and irrigation. It is also advisable, if the condition of the nutrition warrants it, to withhold food for about twelve hours. This must be done only after due deliberation, however, if the cause of the infectious diarrhea is any other organism than the gas bacillus. In all of these cases, unless the babies are taking and retaining sufficient liquid by mouth, it is advisable to give salt solution subcutaneously or by seepage.

Little can be done for excessive vomiting beyond the general measures already detailed, except to withdraw all food entirely and wash out the stomach with a solution of bicarbonate of soda of the strength of one level teaspoonful to the pint of water. In some instances, small amounts of this same solution of bicarbonate of soda, of one of the aërated waters or of ginger ale, will be retained when food and water are not. The vomitus not infrequently contains brownish or reddish flecks or streaks as the result of capillary hemorrhages into the stomach. This sign is of serious, but not necessarily of fatal, import.

The hyperpyrexia is best treated by the use of cold externally. It is very seldom advisable to give the coal tar products to infants to reduce the temperature. Sponge baths of equal parts of alcohol and water, at 90° F., are usually effective. If they are not, fan baths may be tried. Fan baths are given in the following way: The baby is stripped and wrapped in cheesecloth. This is then wet with water at 100° F. and the baby is fanned. The temperature is reduced by the evaporation of the water. The cheesecloth

is wet from time to time as the water evaporates. Babies seldom object to this form of bath. If this is ineffectual, the cold pack at from 60° F. to 70° F. should be tried. Babies seldom bear tub baths well and it is, as a rule, wiser not to use them.

An ice bag may also be applied to the head. It must not be forgotten, however, that a baby's skull is very thin and that the effect of the cold is, therefore, greater than in the adult. This is especially true when the fontanelle is open. Great care must, therefore, be exercised in the use of the ice cap in infancy.

Lowering the temperature of the liquid used in irrigating also aids in reducing the fever. It may be reduced to 100° F. or 95° F. and in desperate cases to 90° F.

The nervous symptoms are very varied. In some instances the babies are stupid, comatose or relaxed. In others they show the typical picture of coma vigil. Marked restlessness is a very common manifestation. Twitching is not uncommon and convulsions not very infrequent. In many instances there are marked signs of meningeal irritation. The head may be retracted, the pupils unequal, the knee-jerks exaggerated, and so on. In fact, the picture may be almost exactly that of meningitis, so much so that a diagnosis can only be made positively by lumbar puncture. The results of this procedure are also sometimes misleading, because the cerebrospinal fluid in this condition sometimes shows a slight globulin test and a moderate excess of mononuclear cells. The pathological condition is presumably one of meningeal irritation or serous meningitis. The treatment of these nervous manifestations is purely symptomatic. Bromide of soda, in doses of from five to ten grains, by mouth, may be given for restlessness and excitement. It may be combined with one or two grains of chloral hydrate. It is ordinarily useless to give drugs by enema in these conditions, as they are almost never retained. If the bromide and chloral do not control the symptoms, morphine may be given by mouth or subcutaneously, in doses of from 1/100 of a grain to 1/32 of a grain. It is always advisable in giving morphine to infants to begin with a very small dose and then increase it, if necessary. An ice bag on the head sometimes helps. When the fontanelle is full, a lumbar puncture will often give relief. Convulsions should be treated in the usual manner.

There is nothing especially characteristic about the manifestations of prostration and collapse in these conditions. They are to be treated in the same way that they are when they occur in other conditions. It is important to remember, however, that all forms of treatment weaken and exhaust the baby. Irrigations must be

omitted and the baby disturbed as little as possible. It must be kept warm and protected in every way. They are likely, however, to be associated with a certain amount of vasomotor paralysis and lowering of the blood pressure. Alcohol is, therefore, contraindicated. Adrenalin is of some value under these circumstances, in doses of from two to ten minims of the 1–1000 solution, given subcutaneously. Its action is much greater when it is given intravenously. Unfortunately, intravenous injection is not an easy matter in infancy. It has practically no effect when given by the stomach. Strychnia is, in general, the most useful of the stimulants, while caffeine and camphor are the best quick stimulants. Strychnia may be given in doses of from 1/1000 to 1/200 of a grain. The dose of the citrate of caffeine by mouth for a baby is from one-eighth to one-half a grain, and of caffeine-sodium benzoate or salicylate subcutaneously about the same. Camphor may be given subcutaneously in oil in doses of from one to two grains.

CHOLERA INFANTUM

There can be no doubt as to the existence of the symptom-complex which is usually designated by the name "cholera infantum." It has all the earmarks of an acute, specific, infectious disease. Hence it seems rational to classify it under the head of infectious diarrhea. No specific microörganism has, however, ever been found for the disease. In fact, it is not certain that it is caused by any form or forms of microörganisms. It is possible that it is merely a peculiar manifestation of some unusual type of intoxication or disturbance of metabolism. However that may be, the symptom-complex is so striking that it deserves description as a separate entity. It is a rare condition. It almost never occurs in children over two years of age and never except in hot weather.

Pathology.—The pathological changes are practically nil. All the tissues are drained of their liquid. There are no lesions of the intestines beyond the evidences of a desquamative catarrh or a moderate hyperemia of the mucous membrane. There may be evidences of cerebral hyperemia and occasionally of edema, but these are usually wanting. The kidneys show evidences of degeneration, but no changes sufficient to account for the symptoms. The other parenchymatous organs also show degenerative changes.

Symptomatology.—The symptoms are due primarily to the action of some toxic substance upon the heart and nervous system, the vasomotor nerves of the intestines being especially affected, and secondarily, to the draining of fluid from the various organs.

The onset of the disease is usually preceded by some of the symptoms of indigestion, but it may develop in an infant apparently perfectly healthy. The development of the symptoms when they once appear is, however, extremely rapid, so rapid, in fact, that a baby may be moribund in five or six hours. The first symptoms are ordinarily restlessness or prostration with more or less abdominal discomfort and a rising temperature. Vomiting begins in a few hours and is accompanied or quickly followed by profuse diarrhea. The first vomitus and stools are made up of whatever happens to be in the stomach and intestines at the time of the onset. After that the vomitus and stools are composed almost entirely of serum. The vomitus is often blood stained. The stools are large, watery, almost colorless and without odor. The reaction is usually acid in the beginning, but quickly becomes neutral and then alkaline. Microscopically they show large numbers of epithelial cells, a few leucocytes and very many bacteria. There is sometimes considerable tenesmus, but in most instances the sphincters are relaxed and the fluid simply runs out of the bowel every few minutes. There is no tenderness in the abdomen and no spasm of the abdominal muscles. The abdomen is usually sunken. The tongue is dry and red.

There is very rapid emaciation as the result of the loss of fluid from the tissues. The face appears pinched, the eyes sunken, the skin dry and the fontanelle depressed. Thirst is a very marked and urgent symptom. The secretion of urine is much diminished. It is concentrated and highly acid. It usually contains albumin and sometimes casts and blood.

On account of the accumulation of blood in the abdominal organs as the result of the vasomotor paralysis of the abdominal vessels and the consequent interference with the peripheral circulation, the extremities become cold and the skin pale and even cyanotic. The surface temperature is usually low, but the rectal temperature is high, ranging from 103° F. to 104° F. In fatal cases it may reach as high as 106° F. or even 108° F.

The pulse is rapid from the beginning and soon becomes very feeble and irregular. The respiration is usually rapid and irregular, but at times slow or sighing. It may be of the Cheyne-Stokes or Biot types.

The infant is usually restless at first and whimpers almost constantly. After a time it becomes listless and stuporous or symptoms of cerebral irritation develop. The head is retracted, the extremities are rigid and twitching and convulsions appear.

Prognosis—The prognosis is a very grave one. It is very

seldom that a baby recovers from this disease. Death usually takes place during the first forty-eight hours after the onset. The disease seems to be self-limited, however, and if the baby survives for two or three days, it usually recovers. Recovery is ordinarily surprisingly rapid when the severity of the illness is taken into consideration. On the other hand, the acute symptoms may abate and be replaced by those of various types of indigestion. Sclerema sometimes develops under these conditions. The babies may even then recover, but ordinarily die after a period of malnutrition.

Treatment.—In such a rapid and fatal disease it is evident that treatment, to be of any avail, must be immediate and vigorous. It is probable that there is a vasomotor paralysis of the gastrointestinal vessels. Hence food and drugs introduced into the alimentary canal cannot possibly be absorbed. They can do no good and undoubtedly may do harm.

The main indications for treatment are: 1, to empty the stomach and bowels of their toxic contents; 2, to supply fluid to the tissues which are being so seriously drained; 3, to restore the surface circulation; 4, to reduce the temperature; 5, to keep the patient alive until the disease has run its course.

Purgatives act too slowly to be of much use in this disease, and the chief reliance must be placed on stomach washing and intestinal irrigation. They are of use in the beginning, but do not do good after the first few hours. It is useless to expect to supply fluids by the mouth. They are almost invariably vomited. Cold, sterile water, in small amounts, may be tried, however. The injection of physiological salt solution into the cellular tissue is the only method of introducing fluid which can be depended upon. It should be given freely in doses of from four to eight ounces at a time and repeated almost as soon as it is absorbed. This not only supplies fluid to the tissues, but assists in eliminating the toxic substances from the blood and in restoring the surface circulation.

Irrigations of cold water tend to restore the surface circulation and also to reduce the temperature. The best methods for restoring the surface circulation are rubbing, mustard baths and the warm pack. These procedures, however, are not those best fitted for the reduction of temperature. For this purpose cold, in the form of sponging, fan baths or packs, must be used. In the treatment of individual patients it is often necessary to determine whether it is the internal congestion or the high temperature which is doing the more harm, and then to treat the more serious condition. The relief of one, however, often aids the other also.

As food cannot be given, the patient must evidently be kept alive

by stimulation. As drugs given by the mouth are not absorbed, this stimulation must be given subcutaneously. The usual stimulants, strychnia, caffeine and camphor, are to be employed. Strychnia may be given in doses of from 1/1000 to 1/200 of a grain, subcutaneously. The dose of caffeine-sodium benzoate or salicylate is from one-eighth to one-half of a grain and that of camphor, one or two grains. The camphor should be given in oil. Atropine is especially useful in these cases. It is possible that it has some special action antagonistic to that of the toxic products of the disease. It is to be used in doses of from 1/500 to 1/800 of a grain, repeated every two or three hours, as necessary. Morphia is indicated when the diarrhea and vomiting are extreme or when the nervous manifestations are very marked. Doses of 1/100 of a grain are usually sufficient. They should be given subcutaneously. Care must be taken not to give too much or to continue it too long.

In case improvement begins, stimulants and water may be given by the mouth, and soon after this, small amounts of food. The best food to give first in these cases is diluted human milk. It is wise to begin with one part of milk and two or three parts of water, giving from one-half to one ounce at a feeding. If this is tolerated, the strength and the amount at a feeding should be increased as rapidly as is possible. There are no very definite indications as to what combination of the food elements should be most suitable, when human milk cannot be obtained. The only thing that is certain is that the food must be a very dilute one. Whey is as likely to agree as anything. If this is tolerated, a mixture containing 0.25% of fat, 5% of milk sugar, 0.75% of whey protein and 0.25% of casein may be given next. If this agrees, the percentages of fat and casein should be gradually increased. If the whey does not agree with the baby, a mixture containing no fat, 2% of milk sugar, 0.75% of protein and 0.75% of starch should be tried. It is better to boil this mixture in order to prevent the formation of large, casein curds. If this mixture is tolerated, the percentages of milk sugar and casein should be increased and fat added cautiously.

CHAPTER XXVI

CONSTIPATION

Constipation is not a disease. It is a condition in which the number of stools is less or the consistency of the stools is greater than is normal for the individual at the given time.

CONSTIPATION IN THE NEW-BORN

Constipation in the new-born must not be confused with those conditions in which the absence of stools is due to congenital malformations of the intestine, such as imperforate rectum and atresia of the intestine, which mechanically prevent the passage of feces. It is ordinarily due at this time to an insufficient intake of food, as the result of delay in the secretion of the breast-milk. In other instances, in which the supply of breast-milk or of artificial food is sufficient, the difficulty seems to be sluggishness of the intestinal peristalsis, apparently from lack of use, or an innate feebleness of the intestinal musculature.

CONSTIPATION IN INFANCY

Etiology.—The etiology of constipation in infancy is a very varied one and several factors are often active in the same case. The causes of constipation at this age can be divided into several classes, each of which can be further subdivided. These classes are so different that they must be considered separately.

General Causes.—These causes, which should, perhaps, be called unclassified, are very different in their nature and in their action. They should always be thought of, however, in attempting to determine the cause of constipation. The first of these causes is heredity. The large number of instances in which constipation is present in both parents and infants makes it almost certain that heredity plays a part in the etiology of constipation in infancy. It is probable, however, that this part is a relatively minor one and that in most instances the presence of constipation in one or both of the parents and their infant is simply a coincidence.

Insufficiency of the thyroid gland is another cause of constipation in infancy which should always be borne in mind. It would, of

course, not be missed in well-marked cases of cretinism, but is easily overlooked when the characteristic signs of thyroid insufficiency are slight or absent.

An insufficient secretion of the intestinal glands or of the liver is presumably at the bottom of certain cases of constipation in infancy. It is very difficult, however, to recognize a deficiency in the secretion of these organs and to distinguish constipation from this cause from that due to minor errors in diet.

Constipation is sometimes the result of the administration of opium, usually in the form of paregoric or "soothing syrup." This cause should never be forgotten in those instances in which no other evident cause can be determined. It must always be remembered in this connection, moreover, that the parents may not be aware that the baby is getting opium, because the drug may be given by a nurse or nursery maid without their knowledge. Constipation in a baby, otherwise apparently well, which is very quiet and which sleeps unusually well, should always suggest opium as its cause.

Mechanical.—The large intestine is relatively longer in comparison to the small intestine in infancy than in later life and its mesentery proportionately longer. The sigmoid flexure makes up a relatively larger portion of the colon than later in life and its mesentery is comparatively long. These anatomical conditions render possible the production of bends and kinks of the colon which, while they do not obstruct the lumen of the gut entirely, hinder the passage of the intestinal contents through it and thus mechanically cause constipation. A Jackson's membrane or some other slight malformation in the vicinity of the cecum may also mechanically interfere with the free passage of the intestinal contents. So also may peritoneal adhesions, resulting from inflammatory processes in the past, whether before or after birth. Still another mechanical cause of constipation in infancy is congenital dilatation of the colon, or Hirschsprung's disease. In this condition constipation often alternates with diarrhea.

Tumors, most often in the pelvis, may also sometimes be the cause of constipation in infancy. In rare instances vesical calculi may be large enough to mechanically interfere with the passage of feces.

Spasmodic.—Fissure of the anus may, on account of the pain which it causes during defecation, result in obstinate constipation. The pain attendant on a movement of the bowels not only makes the baby put off a movement as long as possible but also causes spasmodic contraction of the anal sphincter. Hemorrhoids, al-

though rare in infancy, may cause constipation in the same way. Large, hard stools may also cause spasmodic constipation on account of the pain attendant on their passage. This form of constipation is, for this reason, often a complication of other types. It may persist for a long time after the cause has been removed, the baby being afraid to have a movement because of its memory of the pain associated with it in the past. In rare instances a tonic spasm of the sphincter is the cause of the constipation. The etiology of the spasm in these cases is obscure.

Dietetic.—Abnormalities in the food, either in its quantity or quality, make up one of the two most common of the classes of the causes of constipation in infancy.

The most common abnormalities in breast-milk which result in constipation are an insufficient amount of milk, a dilute milk and a milk low in fat. The cause of the constipation is the same in all. The solids of the milk are so completely absorbed that there is not sufficient residue left to form the normal amount of feces. In rare instances a high percentage of fat in breast-milk is the cause of constipation. The explanation is the same as when there is a high percentage of fat in artificial foods.

Constipation follows when an insufficient amount of an artificial food is given or when the food is too weak, because the solids of the milk are so completely absorbed that there is not sufficient residue left to form the normal amount of feces. An artificial food which is low in fat, although it contains a sufficient amount of carbohydrates and protein, is also often accompanied by constipation. The cause of the constipation in this instance is the fact that the carbohydrates and protein are almost entirely absorbed and therefore make but a small amount of fecal matter, while a considerable proportion of the feces is derived from the fat in the food. A more common cause of constipation in the artificially-fed is an excess of fat in the food. In these instances the fat combines with the earthy alkalis to form the so-called "soap stools." These stools vary in color from light-yellow to gray. They are sometimes large and hard. In other instances they are dry and crumbly, resembling, in typical cases, the stools of a dog which has been eating bones. An excess of starch in the food may also cause constipation. When the constipation is due to this cause, the stools are large, brownish, dry and brittle.

The heating of milk unquestionably predisposes to constipation, but only to a slight extent. It is a far less common cause of constipation than is ordinarily supposed. The boiling, or sterilization, of milk has more influence than does the pasteurization of milk, in

fact, the pasteurization of milk at temperatures below 167° F. has almost no appreciable influence.

One of the most common causes of constipation during the second year is the abuse of milk. A baby of this age should seldom take over thirty-two, or at most forty, ounces of milk in twenty-four hours. Constipation is very likely to result if more is given. Other causes of constipation at this time are an insufficient amount of cereal, orange juice and cooked fruit.

Atonic.—Muscular weakness is the other of the two most common causes of constipation in infancy. The intestinal muscles are always involved, while the abdominal muscles are not infrequently weakened at the same time. One of the most common causes of weakness of the intestinal musculature is prolonged indigestion, especially if associated with fermentation. Rickets is very frequently associated with atonic constipation. General malnutrition, anemia and wasting diseases are other common causes of weakness of the intestinal muscles.

Another cause of muscular weakness is lack of exercise. Many babies are kept too quiet and not allowed to use their muscles sufficiently to keep up their tone. In other instances the constipation is due to the facts that the babies have not been trained to have a movement of the bowels at a regular time and have not been taught to use their muscles in defecation. It must be remembered in this connection that constipation in very young babies may be due simply to the lack of voluntary effort on their part to empty the rectum. In such instances there are no general symptoms of constipation and the bowels move immediately if the rectum is stimulated in some way, as by the introduction of a suppository.

A still further cause of what amounts to atonic constipation is the continued use of laxative drugs. These get the intestines into such bad habits that they do not respond to the normal stimulus.

Symptoms.—It is very difficult to describe the symptoms of constipation in infancy. Constipated babies are often irritable and sleepless. They frequently show evidences of general discomfort. Their tongues are coated, their breath is foul and they suffer from flatulence and colic. All of these symptoms are, however, present in other conditions, especially in those which are not infrequently the cause of constipation. It is very difficult, therefore, in many instances, to determine what symptoms are due to the constipation and what to the primary condition. Pain during defecation is almost invariably present in the spasmodic form. If the constipation is due to trouble low down in the bowel, there are usually no general symptoms associated with it.

Treatment.—The first element in the treatment of constipation in infancy is to establish the etiology, that is, to discover the cause of the constipation. This demands, in most instances, a very careful study of the diet and habits of the infant. Every detail has to be gone into. It also involves a careful physical examination including, in most instances, a rectal examination. The problem can often only be solved by the aid of Roentgenograms taken after bismuth meals or bismuth enemata. Abnormalities in the intestine interfering with the passage of the intestinal contents can often be discovered only in this way. A lack of general symptoms in connection with the constipation suggests that the trouble is in the rectum. If the introduction of a suppository is immediately followed by the passage of a normal stool, the rectum is certainly at fault. The general symptoms are most marked when the constipation is due to disturbance of the digestion in the small intestine.

After the cause is discovered, the treatment must be directed to its removal. Certain causes, such as heredity, cannot, of course, be altered. Others, such as cretinism and the abuse of drugs, can be easily and quickly remedied. Time and the growth of the parts can alone remedy some of the mechanical conditions, such as the long infantile colon and sigmoid flexure. The other mechanical conditions demand operative interference.

When the constipation is due to the pain caused by the passage of large, hard stools, measures should be taken to diminish the size of these stools and to make them softer by regulation of the diet and, if necessary, by the temporary use of mild laxatives. When the pain is due to hemorrhoids, they should be removed. Fissure of the anus can usually be quickly cured by keeping the stools soft and by the application of boracic acid ointment. The application of the nitrate of silver stick will help in some cases. Stretching of the sphincter is almost never necessary in infancy.

The treatment of constipation due to errors in the diet is self-evident. When the dietetic errors are removed the constipation will cease. These errors can be determined in many instances, however, only by the most careful study of the diet and by the microscopic examination of the stools.

The chief element in the treatment of the atonic form of constipation is the relief of the causative condition, whether it be rickets, malnutrition or anemia. Another important element in these cases is the training of the baby to have a movement at a regular time and to use its abdominal muscles. If the condition is due to laxative drugs, they must be stopped.

In most instances it is necessary to relieve the symptom, constipation, while the cause is being removed. The measures to be taken to accomplish this depend to a certain extent on the type of constipation present. When the constipation is due to muscular weakness, massage of the abdomen twice a day for from five to ten minutes is often of considerable assistance. It is of less value in the other types. Foods which stimulate the intestinal peristalsis are also of especial value in this form. Orange juice or prune juice, in doses of from one to four tablespoonfuls daily, may be given during the first year and baked apples and prune pulp during the second year. It is also allowable in some cases to give a few teaspoonfuls of strained peas, string beans or spinach, or asparagus tips, daily, during the last quarter of the second year. Great care must be taken, however, not to disturb the digestion by giving an excessive amount of fruit and vegetables and thus to increase the constipation or to set up a diarrhea. It is rarely advisable to give bran, whether in the form of crackers, cookies, or rolls, to babies, although bran crackers can sometimes be used with advantage toward the end of the second year.

If the stools are hard and dry, water, best given between the feedings, will often be helpful. Finely divided agar agar, in doses of from one to three teaspoonfuls daily, will often keep the feces moist and also increase their bulk. It should be mixed or cooked with the cereals or given in broth. Coarse foods are more likely to do harm than good in this form.

The addition of oatmeal water or jelly to the food of a baby in the latter half of the first year, or the substitution of one of these for barley water, will sometimes aid in relaxing the bowels. In other instances, however, oatmeal has a constipating effect and barley water acts as a laxative. The substitution of one of the dextrins and maltose mixtures for milk or cane sugar sometimes relieves constipation in young babies. The greater the proportion of maltose, the greater, in general, is the laxative action.

If these measures prove ineffectual, it is necessary to move the bowels by the administration of drugs by the mouth or by the stimulation of the intestine from below. When the cause of the constipation is in the rectum, stimulation from below is plainly indicated. When the seat of the trouble is higher up or is a more general one, it is often very difficult to decide which method to adopt. A good general rule is not to use the same method continuously. There is less danger of establishing bad habits, if the methods are varied.

There is more danger of making a baby dependent on stimula-

tion of the rectum to produce a movement than of making it dependent on drugs. This is especially true of suppositories. It is very easy to educate a baby to think that it cannot have a movement of the bowels unless it is reminded of it by the introduction of a suppository. Great care must be exercised for this reason not to establish a bad habit in attempting to train a baby to have a movement at a regular time or on its chair. The simplest and least irritating type of suppository is a roll of paper dipped in sweet oil. Gluten suppositories are less irritating than glycerin suppositories. The soap-stick stands midway between them.

The best and simplest form of enema is that composed of soap and water. No more should be given than is sufficient to produce the desired result. From two to four ounces is usually enough; more may be given if necessary. It is best given with a soft rubber ear-syringe. A fountain-syringe may be used, if desired. If the stools are hard and dry, an enema of from one-half ounce to one ounce of sweet oil, given to be retained, and followed later by a suds enema, if necessary, is often very useful. Glycerin enemas are inadvisable in the treatment of constipation in infants.

The simplest laxative for a baby is milk of magnesia. One teaspoonful a day is usually sufficient, but more may be given, if necessary. It is best to give it all at one dose, preferably at the last feeding at night. Babies take it without question, if it is mixed with their milk. Most babies are not disturbed by it. In a few it causes considerable pain and discomfort and, therefore, has to be omitted. Babies very seldom become dependent upon it.

If milk of magnesia is not well borne, phosphate of soda in doses of from ten to sixty grains may be substituted for it. This is also best given in the milk.

During the latter part of the second year, phenolphthalein, in doses of from one to three grains is often useful. Cascara sagrada in doses of from one-half to one grain, or of from five to thirty drops of one of the liquid preparations, may also be used.

Purgative drugs, such as castor oil and calomel, and to a less extent senna, should not be used continuously in the treatment of constipation. They are too powerful and have a secondary constipating action. Olive oil is useful in some cases. It must never be forgotten, however, that olive oil is a fat and that in those cases in which the constipation is due to an excess of fat in the food it will certainly exaggerate the condition. There is also danger, moreover, of disturbing the digestion with it.

SECTION V

DISEASES OF NUTRITION

CHAPTER XXVII

RICKETS

Rickets is a constitutional disease which is almost certainly due to a disturbance of nutrition. All the organs and tissues of the body are affected, but the chief lesions are in the bones. These lesions are pathognomonic. Their chief characteristic is a local or general disturbance of the normal processes of ossification. Rickets is most common between the sixth and eighteenth months. It seldom occurs earlier and very rarely begins after the third year. It develops, therefore, at a time when the bones are in process of rapid development.

Pathological Anatomy.—The bones grow in length through the formation of bone tissue in the cartilage between the epiphysis and diaphysis. They grow in thickness as the result of the growth of bone from the inner layers of the periosteum. As the bone increases in circumference, the medullary canal is enlarged proportionately by the absorption of the inner layer of bone. Under normal conditions these processes progress in regular order and in clearly defined lines. In rickets there is an overgrowth of the cartilaginous layer between the epiphysis and diaphysis both in width and thickness and it is markedly hyperemic. In this area the zone of proliferation is much enlarged and the cells are arranged irregularly instead of symmetrically, as in normal conditions. The deposition of lime salts and the amount of calcification is, nevertheless, much less than under normal conditions. The epiphyseal centres of ossification are larger, softer and more vascular than normal. There is a similar disturbance in the subperiosteal formation of the shaft. The outer layers of the shaft are thickened, but soft. The medulla of the bone is more hyperemic than normal and the inner layers of the bone also become softened through lack of lime salts.

The visible results of these abnormalities in the growth of the

bones are enlargement of the bones at the epiphyseal lines and at the centres of ossification and unnatural flexibility of the bones. On account of this increased flexibility, deformities and sometimes fractures are produced as the result of pressure or weight bearing.

Etiology.—While there is but little doubt that rickets is due to a disturbance of the metabolism, chiefly of calcium and phosphorus, and that the bony changes are due to some interference with the deposition of lime salts, it is still a fact that the cause of rickets is not positively known. Many theories have been advanced, however, as to its causation, all of which have a certain amount of evidence in their favor.

Considerable importance has been attached to heredity as a predisposing factor in the etiology. It is believed that the predisposition is transmitted especially through the mother. Siegert [1] is the chief exponent of this theory. It has, however, received but little support.

Another theory is that it is due to improper hygienic surroundings and lack of fresh air and sunlight. Evidence in favor of this theory is that it is more common in the city than in the country, in the winter than in the summer, in the poor than in the well-to-do. It is also apparently more common in this country in those races whose new surroundings are most different from those to which they were accustomed. The children of a pastoral race are most likely to develop it when confined to a city. This is also true of wild animals. They never have the disease when free, but often develop it when confined in zoölogical gardens.[2]

The most generally accepted theory is that, other things being equal, it is much less common in the breast-fed than in the artificially-fed, unless lactation is unduly prolonged. It is also more common when the artificial feeding is bad than when it is rational.

It has also been thought recently that it is infectious in origin.[3] Certain animal experiments have seemed to give positive results. In these experiments a diplococcus was found in the bones of young animals which were clinically rachitic.[4] The evidence in favor of the infectious origin of the disease is, however, most conclusive.

Attempts have been made in recent years to prove that some

[1] Siegert: Jahrb. f. Kinderh., 1903, lviii, 929.

[2] Lehnerdt: Ergebn. d. inn. Med. u. Kinderh., 1910, vi, 120.

[3] Oppenheimer and Hagenbach: Burkhardt quoted by Wieland in Bruneg and Schwalbe Handbuch der Allgemeine Pathologie und der Pathologischen Anatomie des Kindesalters, Wiesbaden, 1913, ii, pt. I, p. 260.

[4] Morpurgo: Verhandl. d. Deutsch. path. Gesellsch., 1900, iii, 40, Ibid. 1909, xiii, 51; Schmorl: Ergebn. d. inn. med. u. Kinderh., 1909, iv, 403; Koch: Ztschr. f. Hyg. u. Infectionskr., 1911, lxix, 436.

of the diseases of metabolism, including rickets, are due to a disturbance of the function of certain of the glands which have an internal secretion.

They are respectively the thyroid, parathyroid, adrenal and thymus glands (Mettenheimer,[1] Matti,[2] Howland, and his associates [3] repeated the experiments on animals, using suitable controls, and were unable to produce rickets in any animals in which the thymus was removed. It seems, therefore, as if the work upon which was based the evidence that the thymus had some etiological relation to rickets, was not properly carried out.

Kassowitz [4] believes that the increased vascularity of the bone marrow and epiphyses is the principal feature of rickets and explains the abnormally wide zone of growth, and that these blood vessels erode the bone.

Artificial Rickets in Animals.—Most investigators who have undertaken to reproduce rickets in animals have assumed that it is due to some disturbance in the calcium metabolism. They have assumed that it results from a calcium starvation because of too little calcium in the food, that there is sufficient calcium in the food but for some reason it is not absorbed in normal amounts, or finally that it is absorbed in normal amounts but the bones are unable to utilize it in the normal manner. Experiments on animals have given varying results. In most instances when animals have been fed on a food deficient in calcium, on an acid food or on a combination of the two, they have become clinically rachitic [5] with enlarged epiphyses. The microscopic appearance of such bones differs from that in true rickets in that the zone of proliferation is much narrower. Miwa and Stöeltzner's [6] experiments lead them to differentiate this condition from true rickets in infants and they give it the name of pseudorachitic osteoporosis. The bones from such animals have a very low ash and calcium content, but have not lost relatively as much magnesium as the bones in true rickets. In the former the loss of phosphoric acid goes hand in hand with the loss of calcium, while in the latter there is relatively less phosphorus lost than calcium.

Aron and Sebauer [7] produced artificial rickets in dogs without changing the calcium content in the muscles, although that in the

[1] Quoted by E. Wieland, *loc. cit.*
[2] Matti: Mitt. auns den Grenzgebieten der Med. u. Chir., 1911–12, xxiv, 665.
[3] Reported at Stockbridge, 1914, Am. Ped. Soc.
[4] Kassowitz: Jahrb. f. Kinderh., 1912, N. F. lxxvi, 369.
[5] Schmorl: Ergebn. d. inn. Med. u. Kinderh., 1909, iv, 403.
[6] Miwa and Stöeltzner: Beitr. z. path. Anat. u. allg. Path., 1898, xxiv, 578.
[7] Aron and Sebauer: Biochem: Zeitschr., 1908, viii, I.

bones was greatly diminished. This fact will be referred to again in the discussion of human rickets.

Calcium Metabolism in Health and in Rickets.[1]—The skeleton of a newly-born baby, weighing 2,600 grams, weighs 445 grams, the muscles 625 grams, the skin 379 grams, and the brain 342 grams.[2] The dried bones of a newly-born infant contain 60% to 65% of ash and 40% to 45% of organic material. The amount of ash in the bone varies from birth onward. At first the ash increases, but during the second year it decreases to about 55%, with a corresponding increase in the organic material. At the end of the second year the ash again begins to increase until it reaches the 68% of the dried bone substance found in adults.[3] The calcium oxide is distributed through the body in the following manner: muscles 0.03%, skin 0.02%, brain 0.107% and skeleton 5.4%. There is in the whole body 25 grams of CaO.[4] Camerer and Söldner [5] give 1.019 grams to every 100 grams of body weight as the average amount of CaO in the newly-born.

Schabad [6] says that the weight of the skeleton is 16% of the total body weight during the first year of life. The calcium content of the skeleton is 1.25% of the body weight and 7.7% of the skeletal weight. The largest deposit of calcium takes place during the period of greatest growth, viz., in the breast-fed infant between the second and fourth months and in the bottle-fed infant between the second and sixth months.

Calcium in Milk.—Examination of the metabolism experiments in rickets shows that in artificial feeding the amount of calcium usually given is so large that there is no possibility of a calcium deficit in the food. When the infant is fed with human milk, the situation is different. The percentage of calcium may vary from 0.03% to 0.08%, the lower limit of that taken by healthy nurslings being about 0.034%, while the average is about 0.044%. The calcium content of milk decreases as lactation progresses from 0.045% to 0.031%.[7] It is clear, therefore, that the milk secreted in early lactation will have a higher percentage than that in later lactation. This does not necessarily mean that the total daily

[1] Much of this section is taken from Orgler: Ergeb. d. inn. Med. u. Kinderh., 1912, viii, 142.

[2] Vierordt: Gerhardt's Handb. d. Kinderh., 1877, i, 53.

[3] Schabad: Arch. f. Kinderh., 1909–10, lii, 47.

[4] Brubacher: Zeitschr. f. Biol., 1890, xxvii, 517.

[5] Camerer and Söldner: Zeitschr. f. Biol., xxxix, 173; xl, 1900, 529; 1902, xliii, 1.

[6] Schabad: Arch. f. Kinderh., 1910, liii, 380.

[7] Bahrdt and Edelstein: Jahrb. f. Kinderh., 1910, lxxii, 16 (Suppl.); Schabad: Jahrb. f. Kinderh., 1911, lxxiv, 511.

amount of calcium received will be any different in early and late lactation, because in early lactation less milk is secreted than in later lactation. This may explain the fact why one nursling developed rickets on 0.04% of CaO.

Dibbelt [1] reports that he was able to increase the CaO content in human milk by giving Ca to the mother, but no subsequent investigators have been able to confirm these results.[2]

Calcium Requirements of Infants.—Orgler concludes after a long discussion that unless an infant absorbs at least 0.13 grams of CaO per day it will become rachitic. It must be borne in mind, however, that Tobler and Noll's [3] baby absorbed only 0.054 grams and yet did not acquire rickets. The average of the amount of calcium taken by all infants is between 0.17 grams and 0.18 grams. The normal infant takes as a rule only as much calcium from human milk as it requires for growth.[4] It must be remembered in this connection, however, that the amount of some of the other food components may be so disproportionately high (for example fat) that the infant receives so many calories in a concentrated food that it does not take enough in amount to give it the amount of calcium it requires, even though the percentage of calcium is within normal limits. Infants have been reported to become rachitic receiving 0.088% CaO.

Calcium Metabolism.—The methods of quantitating the salts in the food and excretions of the body are very difficult and certain authorities say that they are all unreliable with the exception of Macrudden's method for Calcium. Since there is so much doubt as to the accuracy of the methods used in obtaining the following information, it must all be considered with the inaccuracies well in mind.

Calcium is in the milk principally in organic combination. Both organic and inorganic calcium may be absorbed by the body. The calcium in the food goes into solution in the stomach. From 5% to 10% of it appears in the urine after absorption, while the rest of the calcium that is not retained in the body is excreted through the feces. This may pass directly through the intestines into the feces or indirectly, viz.: it may be absorbed in the small intestine and excreted again in the large intestine.[5] Most of the calcium

[1] Dibbelt: Ziegler's Beitr., 1910, xlviii, 147.

[2] Bahrdt and Edelstein: Jahrb. f. Kinderh., 1910, lxxii, 16 (Suppl.); Schabad: Jahrb. f. Kinderh., 1911, lxxiv, 511.

[3] Tobler and Noll: Monatsschr. f. Kinderh., 1910–11, ix, 210.

[4] Aron: Biochem. Zeitschr., 1908, xii, 28.

[5] First shown in dogs by E. Voit: Zeitschr. f. Biol., 1880, xvi, 55.

excreted in the urine is combined with phosphoric acid, but a small amount is combined with carbonic, sulphuric and uric acids.[1]

The most striking fact in the chemistry of rickets is that the bones in rickets as compared to the normal have a diminished amount of calcium and phosphorus and an increased amount of water. The following table taken from Orgler [2] illustrates this fact very well: This table was compiled by Orgler from Schabad: [3]

TABLE 49

	Normal Ribs	*Normal* Occiput	*Rachitis* Ribs	*Rachitis* Occiput
Water	14.4–329	13.0–16.1	42.4–66.4	29.0–35.9
Organic substances	26.9–39.1	32.2–36.5	20.7–27.4	26.1–31.6
Ash	40.2–46.6	47.6–51.7	7.9–32.0	34.3–40.6
CaO	21.7–25.3	26.3–27.9	4.2–16.8	19.0–24.1
P_2O_5	12.3–18.9	18.1–20.7	3.3–12.8	13.7–17.8

These changes are less marked in mild than in severe rickets.

The influence of the other food components on the calcium metabolism.—*Proteins.*—There are very few experiments that have any bearing on the subject, but those that can be utilized [4] seem to show that the proteins have no influence on the calcium retention.

Fat.—According to some writers fat has a marked influence on the calcium metabolism, as increased amounts cause a negative calcium balance.[5] The following table from Orgler serves to illustrate this point:

TABLE 50

	I. Groeger *(a) skim milk* *N*	*CaO*	*(Rothberg [6])* *(b) cream* *N*	*CaO*	*Steinitz II,[7]* *milk* *CaO*	*cream* *CaO*
Food	2.963	0.975	3.400	0.927	0.398	0.378
Urine	2.499	0.020	2.625	0.0	0.005	0.0
Feces	0.315	0.818	0.381	1.125	0.355	0.412
Balance	+0.149	+0.137	+0.394	—0.198	+0.038	—0.034

[1] Albu-Neuberg: Mineralstoffwechsel, Berlin, 1906, 116.

[2] Made up from figures of Schabad: Arch. f. Kinderh., 1909–1910, lii, 47, 63; 1910, liii, 380, 1910, liv, 83.

[3] Schabad: Zur Bedeutung des Kalkes in der Pathologie der Rachitis: Arch. f. Kinderh., 1910, lii, 47 and 63; 1910, liii, 380; 1910, liv, 83.

[4] Tada: Monatsschr. f. Kinderh., 1905–06, iv, 118.

[5] Freund: Jahrb. f. Kinderh., 1905, lxi, 36.

[6] Rothberg: Jahrb. f. Kinderh., 1907, lxvi, 69.

[7] Steinitz: Jahrb. f. Kinderh., 1903, lvii, 689.

In other instances increasing amounts of fat in the food have no influence on the Ca metabolism, as is shown by the following work of Freund: [1]

TABLE 51

	Arndt $^5/_{12}$ *milk* *Water* *CaO*	*Whole milk* *CaO*	*Steinitz* ½ *milk* *CaO*	*Cream* *CaO*
Food	0.478	0.857	0.414	0.314
Urine	0.0	0.022		
Feces	0.409	0.467	0.387	0.216
Balance	+0.069	+0.368	+0.027	+0.098

Carbohydrates.—Up to recently there were no experiments free from error showing the influence of carbohydrate on the retention of calcium. In 1913 Howland [2] reported the results of a study of the calcium metabolism as it was influenced by carbohydrates. A milk mixture without any carbohydrate was followed by a very slight positive or by a negative balance of calcium. When the same mixture was given with carbohydrate added, even though the carbohydrate was a small quantity of cereal, a positive calcium balance often resulted, and when sugar was given the calcium balance was practically always positive. This work seems to indicate that carbohydrate has a very marked influence on the retention of calcium. There are no figures to show what effect an excess of carbohydrate has on the calcium metabolism.

Salts.—There are no studies to show the effect of the sodium or potassium salts on the retention of calcium in infants. The effect of an absence of organic material in the food, as in fasting, is also unknown.

Cronheim and Müller [3] reported that boiling milk influenced the calcium retention, but Arndt,[4] who used better methods, showed that boiling had no effect on the retention of calcium.

During the early stage of florid rickets [5] the calcium balance is either diminished or negative. This disturbance in the calcium metabolism may be present some time before the appearance of

[1] Freund: *loc. cit.*

[2] Reported before the Am. Pediatric Soc., Washington meeting, May, 1913. Not yet published.

[3] Cronheim and Müller: Jahrb. f. Kinderh., 1903, lvii, 45.

[4] Quoted by Orgler—*loc. cit.*

[5] Schabad: Arch. f. Kinderh., 1910, liii, 380.

any of the clinical signs of rickets.[1] As the disease becomes well developed, the calcium balance is either below the average or within normal limits. When convalescence or cure commences there is a greatly increased retention of calcium, which shows itself earlier than does clinical improvement. During this period two or three times as much calcium is retained as in the normal, and when cure is complete the calcium retention again becomes normal.

The increased excretion of calcium from the body in florid rickets, goes on exclusively through the intestines, while at the same time there is less calcium than usual excreted through the urine.[2]

Phosphorus metabolism like the calcium metabolism is influenced by the kind of food given.[3] There is relatively so much phosphorus excreted that it cannot all come from the bones and presumably comes from the nervous system.[4] The relation between the urinary and fecal phosphorus in healthy nurslings is 80:20 and in rachitic nurslings 65:35, while in the healthy bottle-fed infant it is 60:40 and the rachitic artificially-fed 40:60. During convalescence from rickets, the total excretion of phosphorus is lower than normal, and the relation of the urinary to the fecal phosphorus returns to the normal figures. Calcium is excreted in the feces with phosphoric acid or fatty acid, and it is conceivable that an increase of either of these substances may increase the calcium excretion.

Analyses of both rachitic and healthy bones show that the complex salt $Ca_2(PO_4)_2 3CaCO_3$ is the same in both instances. Potassium, sodium and chlorine are the same in both. Magnesium is increased from 0.50% in the normal bone to 0.53–0.74% in rachitic bone.[5]

The muscles in rickets give evidence of the calcium loss from the body. They contain less calcium than do normal muscles,[6] the amount of the deficiency varying directly with the severity of the disease.

The calcium content of the other organs is not diminished in rickets. Pathologically, rachitic muscles show an excessive thinning of the muscle fibres with loss of striation, accompanied by an increase in the number of cell nuclei. These changes are most marked in the most severe cases.

[1] Birk and Orgler: Monatsschr. f. Kinderh., 1910–11, ix, 544.

[2] Schabad: Arch. f. Kinderh., 1910, liii, 380; Dibbelt: Verhandl. der Deutsch. path. Gesellsch., 1910, xiv, 294.

[3] Albu and Neuberg: *loc. cit.*, p. 144.

[4] Schabad: Arch. f. Kinderh., 1910, liv, 83.

[5] Gassmann: Hoppe-Seyler's Zeitschr. f. Phys. Chem., 1910–1911, lxx, 161.

[6] Aschenheim and Kaumheimer: Monatsschr. f. Kinderh., 1911–12, x, 435.

Treatment.—What little evidence there is derived from experiments on animals goes to show that, while a deficiency of calcium in the food causes a disturbance in the ossification of the bones, it does not produce rickets. It is evident, moreover, from the figures which have just been given, that there never is a deficiency of calcium in artificial foods, of which cow's milk forms the basis. There is, therefore, no justification whatever for giving calcium to rachitic babies that are taking cow's milk. It is barely possible, but extremely improbable, that a nursing baby may not get enough calcium in its food. Judging from the results of animal experimentation, such a deficiency would not, however, cause rickets. Nevertheless, it might be justifiable to give a breast-fed rachitic baby some form of calcium. There is no evident reason why one form of calcium should not be as useful as another under these circumstances. In any event, only a small amount would be required. It is probably useless to attempt to increase the calcium in the milk by giving calcium to the mother. If rachitic babies are taking neither human milk nor cow's milk and are, therefore, not getting enough calcium in their food, they should be given one or the other. It will then be unnecessary to give them calcium. It is possible that a baby that is taking a very rich food may take so little of it that it does not get enough calcium. The remedy for this condition is to dilute the food so that the baby will take more of it, rather than to give calcium.

There are very few data as to the relation of the other food elements to the metabolism of calcium. It is possible that the presence of a large excess of fat in the food may, by combining with the calcium in the food, interfere with its absorption and, therefore, with its retention. The evidence as to this fact is, however, inconclusive. There is, on the other hand, a certain amount of evidence which goes to show that the addition of a carbohydrate, whether sugar or starch, to a food, the basis of which is cow's milk, favors the retention of calcium. Variations in the amount of protein in the food have no apparent effect on the metabolism of calcium, but it must be remembered in this connection that a large part of the calcium in milk is in combination with protein, a deficiency of which might cause a deficiency of calcium. Neither do variations in the amount of sodium and potassium. There are no data as to the effect of variations in the amount of the other salts.

Other things being equal, rickets is much less common and much less severe in breast-fed than in artificially-fed babies. The best food for the rachitic baby is, therefore, good human milk. If this

cannot be obtained, the next best food must be selected. This is, necessarily, some form of modified cow's milk. There are no very definite general indications, based on our knowledge of the metabolism in rickets, as to what the composition of this food should be. What little experimental evidence there is, however, suggests that it is advisable to avoid high percentages of fat and to give percentages of carbohydrates well up to the normal limits. These points should be borne in mind, therefore, in deciding upon the composition of the food. They are of but comparatively little importance, however, and should be disregarded if they conflict with the evidence furnished by the symptoms and stools as to the digestive capacity of the individual infant. The chief object in the selection of the food for the rachitic baby, as well as for all other babies, is to fit the food to the digestive capacity of the individual infant at the given time. That is, the composition of the food for a rachitic baby should be decided upon in the same way as that of any other baby, bearing in mind that perhaps it may be advisable to keep the percentage of fat lower and that of the carbohydrates higher than would ordinarily be done.

There has been much discussion as to whether cod-liver oil and phosphorus, either alone or in combination, are of advantage in the treatment of rickets. It would seem fairly definite, however, from the experimental data as to the effect of large amounts of fat in the food on the metabolism and retention of calcium, that cod-liver oil might not only do no good but perhaps active harm. The evidence as to the action of phosphorus, whether alone or in combination with cod-liver oil, which is summed up briefly below, is conflicting.

Kassowitz [1] first recommended phosphorus in the treatment of rachitis. His original prescription, known as phosphorlebertan (phosphori 0.01, ol. jecor aselli, ad 250), still holds first place in Germany in the treatment of rachitis. Kissel [2] found in his experiments on animals that phosphorus had absolutely no effect on the skeletal system, and concluded that there was no ground for its use. Despite this evidence phosphorus continues to be used and many experiments have been performed to prove its efficiency.

Birk [3] and Schabad [4] both concluded that phosphorus in therapeutic doses does not affect the calcium metabolism in healthy children. Such children take only as much phosphorus as they

[1] Kassowitz: Ztschr. f. klin. Med., 1883–4, vii, 36.
[2] Kissel: Virchow's Arch. f. path. Anat., 1896, cxliv, 94.
[3] Birk: Monatsschr. f. Kinderh., 1908–09, vii, 450.
[4] Schabad: Ztschr. f. klin. Med., 1909, lxvii, 454.

need for growth regardless of the amount in the food. In rachitis cod-liver oil increases the retention of phosphorus and calcium and this action is intensified by the addition of phosphorus to the oil.[1] The increased retention of calcium starts three to five days after giving phosphorus and gradually diminishes until at the end of two months it is again normal. This is because of the increased absorption and decreased excretion through the urine and feces. The question then came up as to whether oils as such in combination with phosphorus have a therapeutic action on rachitis. Schabad [2] investigated the action of phosphorus, cod-liver oil and "sesamol" on the metabolism of calcium, phosphorus, fat and nitrogen and found that "sesamol" and phosphorus did not help rachitis, while cod-liver oil plus phosphorus increased the retention of phosphorus and calcium and the absorption of fat and nitrogen. Schabad and Sorochowitsch [3] used lipanin, *i. e.*, olive, a substitute for cod-liver oil, which was supposed to be easily absorbed because it contained free fatty acids. They concluded from their metabolism experiments that lipanin and olive oil increase the absorption of nitrogen and fat but that lipanin has no advantage over olive oil. Lipanin does not increase the retention of calcium in rachitis and is therefore not as good as cod-liver oil in the treatment of rachitis. They say in their most recent article [4] that sometimes phosphorus and cod-liver oil does not have a favorable action on the retention of calcium in rachitis, especially if the disease is not approaching a convalescence. At other times it has a favorable action on the calcium retention. They experimented with various other salts combined with cod-liver oil and found that a calcium acetate cod-liver oil had the most favorable action on rachitis because it contained much more calcium. Most recently Caroline Towles [5] did a series of metabolism experiments in von Pirquet's clinic in Breslau and was unable to demonstrate that phosphorus cod-liver oil had any action at all on acute rachitis.

It is very difficult to draw any conclusions from this evidence as to the advisability of using cod-liver oil and phosphorus in the treatment of rickets. It is probably safe to conclude, however, that it is not advisable to give large doses of cod-liver oil or any other fat. It is also probably safe to conclude that phosphorus may do good and that, at any rate, it does no harm if properly used. If

[1] Schabad: Ztschr. f. klin. Med., 1909, lxviii, 94.
[2] Schabad: Ztschr. f. klin. Med., 1909–10, lxix, 435.
[3] Schabad and Sorochowitsch: Monatsschr. f. Kinderh., 1910–11, ix, 659.
[4] Schabad and Sorochowitsch: Monatsschr. f. Kinderh., 1911–12, x, 12.
[5] Towles: Ztschr. f. Kinderh., 1910–11, i, 346.

phosphorus is used, it is probably best to give it in combination with cod-liver oil. The best preparation of phosphorus is phosphorated oil. A minim of this preparation contains about 1/115 of a grain of phosphorus. The dose for a baby is from one-half of a minim to two minims, two or three times daily. Too much should not, however, be expected from it. It is liable to disturb the stomach and should be given after food.

An abundance of fresh air and sunlight is of the greatest importance in the treatment of rickets. Everything should be done to improve the hygienic surroundings. Massage undoubtedly does good. The advantage of salt baths is problematical. Iron should be given, if there is anemia. Other treatment can be only symptomatic.

CHAPTER XXVIII

INFANTILE SCURVY

Scurvy is a constitutional disease due to a disturbance of the nutrition. The disturbance of nutrition is the result of some prolonged error in the diet. The error in the diet is in all probability the absence or marked diminution of some constituent or constituents of the food essential for the carrying on of the normal metabolic processes and for growth. It is not known exactly what these constituents are, but it is very probable that they are of the nature of vitamins. The chief characteristic of the disease is a tendency to hemorrhage. Infantile scurvy is the same disease as scurvy in the adult. Scurvy and rickets, although often associated, are two distinct diseases.

PATHOLOGICAL ANATOMY

The bone marrow shows characteristic changes. These are most marked at the ends of the diaphyses of the long bones and the anterior ends of the ribs. The bone marrow, which is normally rich in lymphoid cells, loses its lymphoid character and is converted into a tissue poor in cellular elements, that contains relatively few blood vessels. This tissue consists of a homogeneous ground substance containing spindle and stellate cells. There is still much calcified ground substance, but it has not been converted into true bone. As the result of the interference with the normal processes of ossification, the cortex of the bones is thinner and more brittle than normal and the density of the bone is materially diminished at the epiphyseal line. Fractures of the shafts occur very readily, therefore, as the result of very slight injuries. These occur most often at or near the epiphyseal lines. The epiphyses are often loosened and separated. Marked displacement of the epiphysis is, however, uncommon because the periosteum usually remains intact.

The periosteum of the long bones is thickened and congested, but shows no excess of leucocytes or small round cells. Hemorrhages between the periosteum and the bone are very common and may be very extensive. They may break through the perios-

teum into the surrounding tissues. Small hemorrhages in the marrow of the bones are also probably not at all uncommon, but can hardly be recognized clinically. Subperiosteal hemorrhages are much more common in the lower than in the upper extremities.

Hemorrhages may occur in any of the internal organs. They are common in the skin and are found at autopsy in most of the serous membranes. They may also occur in the intestinal mucosa. Hematuria, without inflammatory changes in the kidney, is common. A hemorrhagic condition of the gums is a common symptom when the teeth have erupted. It is, however, very uncommon before the teeth have appeared. Hemorrhage sometimes takes place in the orbit, pushing the eye forward, also under the dura or into the joints.

Hess and Fish[1] have recently made a study of the blood in this disease to determine the cause of the hemorrhages. They found that the clotting power of the blood in scurvy was, as a rule, slightly diminished. This diminution was not, however, constant and cannot, therefore, be regarded as an essential manifestation of the disease or sufficient to account for the hemorrhagic tendency so characteristic of it. They found that there was no deficiency of calcium or blood-platelets and no excess of antithrombin. They then studied the blood vessels by means of what they term the "capillary resistance test" and found that there was a weakness of the vessel walls in scurvy. This weakness is also present in other conditions than scurvy and is, therefore, not pathognomonic of it. It seems evident from their work, however, that the hemorrhagic tendency in scurvy is due to a weakness of the vessel walls rather than to any change in the blood.

ETIOLOGY

Certain facts are definitely known as to the etiology of scurvy. One of them is that it occurs most frequently in the last half of the first year and in the first quarter of the second year. More than four-fifths of the cases develop during this period and half of them between the seventh and tenth months. It has been seen, however, in infants under one month old and occasionally develops during the third and fourth years. It is also true that the hygienic surroundings have no influence on its occurrence. The previous condition of health is unimportant and diseases of the digestive tract do not predispose to its development. There is no evidence in any way satisfactory to suggest that it is microbic in origin.

[1] Amer. Jour. Diseases of Children, 1914, viii, 385.

Clinical experience apparently proves conclusively that scurvy is caused by some error in the diet. Furthermore, it seems to prove that it is due to some prolonged error in diet rather than to a temporary unsuitability of the food. The analysis of a considerable series of cases seems to show, moreover, that the disease is due to the lack of some essential element in the food rather than to the presence of some abnormal element or elements. Further than this the clinical evidence is rather unsatisfactory. It is true that scurvy is infinitely more common in artificially-fed infants than in the breast-fed. It does occur, however, in the breast-fed. This proves that it is not due simply to the lack of breast-milk. It occurs very frequently in babies that are taking proprietary foods prepared without milk. It occurs also in babies that are taking the proprietary foods prepared with milk and in babies that are taking milk without the addition of proprietary foods. These facts show that scurvy cannot be due simply to the presence of the proprietary foods or to either the presence or absence of milk in the diet. Scurvy occurs in babies that are taking condensed milk, boiled milk, pasteurized milk and raw milk, which apparently shows that the heating of milk, even if it is a factor in the production of scurvy, is not the only cause. The report of the Committee of the American Pediatric Society in 1898 emphasizes the difficulties in arriving at the dietetic cause or causes of scurvy. They were only able to arrive at the conclusion, after a careful analysis of 379 cases, that "the farther a food is removed in character from the natural food of a child the more likely its use is to be followed by the development of scurvy." [1] The analysis of the authors' own cases shows the same discrepancy in the foods which were being taken when scurvy developed that has been found in all other series. It seems to show also, however, that the absence of "freshness" and the heating of the food are very important elements in the production of scurvy. In the more recent cases, overheating of the food was found in a larger proportion of the cases than was any other of the conditions to which it has been thought scurvy may be due. [2]

Effect of Heat.— It is very difficult to draw any positive conclusions from the literature of the subject as to whether the heating of milk, whether to the temperature of pasteurization or to that of boiling, produces scurvy in infants. The evidence presented is conflicting and inconclusive. In most instances the number of infants studied is small and the data as to the degree and duration

[1] Archives of Pediatrics, 1898, xv, 481.

[2] Morse: Jour. Amer. Med. Assn., 1906, xlvi, 1073, and Boston Medical and Surgical Journal, 1914, clxx, 504.

of the heating are incomplete. The statistics of Variot [1] and Carel [2] which are always brought forward to show that the heating of milk does not cause scurvy, are of little or no value, because at the time when these observations were made scurvy was not sufficiently well known in France to be recognized unless of a most extreme type. The strongest evidence against the heating of milk being the cause of scurvy is found in the work of Lane-Clapon in the Infant Consultation of the Naunyn Strasse in Berlin, in which a considerable series of babies were fed on boiled milk for long periods and did not develop scurvy.[3]

The strongest clinical evidence in favor of the view that the heating of milk produces scurvy is the fact that all large series of cases of scurvy show that a considerable proportion of the patients were fed on heated milk, more of them, however, on sterilized, boiled or scalded, than on pasteurized milk.[4] It is impossible to prove, however, that it was the heating of the milk and not the composition of the food which caused the scurvy in these babies. It is evident that when an individual baby is fed on a heated modified milk it is impossible to know, if scurvy develops, whether it is due in the special case to the heating or to the composition of the milk. It can be only a matter of opinion. Further evidence against the heating of milk causing scurvy is that scurvy sometimes develops in the breast-fed and in babies fed on raw milk. Still further evidence are Plantanza's observations [5] that although scurvy developed more frequently in babies fed on heated milk which was not used at once than on raw milk, it did not develop when fresh milk was heated and used at once.

The results of experiments on animals with raw and heated milk are few and inconclusive. So many other factors have entered into the experiments that the results are practically without value. The only investigation of importance is that of Frölich.[6] He was able to produce scorbutus in guinea pigs by exclusive feeding with either raw or cooked cow's milk, although not as perfectly as by exclusive grain feeding. When fed on oats and raw milk they did

[1] Variot: Compt. rend. Acad. d. Sci., 1904, cxxxix, p. 1002.

[2] Carel: Le lait sterilisé Thèse de Paris, 1902–3.

[3] Reports to the Local Government Board on Public Health, 1912, New Series, No. 63. The literature of the subject up to this time is given in this article.

[4] Sill: Medical Record, New York, 1902, lxii, p. 1016; Hess and Fish: Amer. Jour. Dis. of Children, 1914, viii, 385; Morse, *loc. cit:* Report Amer. Ped. Soc'y Archives of Pediatrics, 1898, xv, 481.

[5] Archiv. f. Kinderheilkunde., 1912, lviii, 155.

[6] Zeit. f. Hygiene u. Infectionskrankheiten, 1912, lxxii, 155.

not develop scorbutus, but when fed on oats and cooked milk they did. Bolle, and after him Bartenstein [1] tried the effect of heating milk and found that heating it for a short time had no especial effect on guinea pigs. When however, the milk was heated for a long time at a high temperature the guinea pigs died and single bones showed changes which Bolle identified as scorbutus.

Experimental Scorbutus in Animals.—Holst and Frölich were the first to produce scorbutus in animals, in 1907. They and Fürst have continued their work up to the present time.[2] Talbot and Peterson [3] have recently repeated and confirmed their experiments. They found that when guinea pigs were fed exclusively on various forms of bread and grain, they died in from four to six weeks of a disease which in its symptoms and pathological anatomy corresponded with human scorbutus. They believed that the symptoms and pathological changes were caused by the diet. Others claimed, however, that they were the result of inanition from starvation. They then fed guinea pigs on fresh white cabbage, dandelions or carrots in such small amounts that the animals lost from 30% to 40% of their weight. None of these animals developed scorbutus, whereas animals that were fed on dried grains or bread and lost a like amount of weight or relatively a few grammes, showed scorbutic changes. These experiments proved conclusively that the scorbutic changes were not due to simple inanition. It is interesting to note in this connection that there are records of cases of human scorbutus which followed a diet which was the same or similar to that given to the guinea pigs.

They found that scorbutus in guinea pigs is relieved or cured by fresh vegetables in the same way that it is in man. The antiscorbutic properties of the vegetables are usually, if not always, weakened by the process of cooking, but are rarely entirely destroyed. There seems to be some connection between the intensity of the heat used in cooking and the loss of the therapeutic properties. For example, white cabbages are of less therapeutic value when they are cooked at from 110° C. to 120° C. than when they are boiled.

The fresh vegetables lose their antiscorbutic properties in varying degrees when they are dried. Among those which they in-

[1] Bolle and Bartenstein: quoted by Hart, Virchow's Archiv. f. path. Anat. u. Phys., 1912, ccviii, 367.

[2] Holst and Frölich: Journal of Hygiene, Cambridge, 1907, vii, 619; Norsk Magazin for Laegevedenskaben, 1910, lxxi, No. 3; Zeit. f. Hygiene u. Infectionskrankheiten, 1912, lxxii, Part One; Fürst: Norsk Magazin for Laegevedenskaben, 1912, lxxiii, No. 1.

[3] Boston Medical and Surgical Journal, 1913, clxix, 232.

vestigated are potatoes, carrots, dandelions and white cabbage. These vegetables are affected differently by drying. Dandelions lose their therapeutic value immediately on drying, while white cabbage retains it longer when kept in an open vessel in an incubator at 37° C. than when it is kept at room temperature. Freshly pressed cabbage juice quickly loses its antiscorbutic properties when it is heated at from 60° C. to 100° C. for ten minutes. The same thing happens when it is preserved for a long time either at room temperature or in an ice chest. Pressed dandelion juice also loses its prophylactic properties when heated for a short time.

In contradistinction to the above, lemon juice will withstand for a long time the same heat that will weaken or entirely destroy the virtue of white cabbage or dandelion juice. Raspberry juice can be cooked for one hour at 100° C. without losing any of its antiscorbutic properties. Holst and Frölich thought there must be some connection between the acidity of these juices and their antiscorbutic properties and they were able to increase the resistance of white cabbage and dandelion juice to heat by the addition of acids. They were not able to increase this resistance so that it would stand prolonged heating. They were unable to determine the nature of the antiscorbutic bodies by dialysis, by extraction or other experimental methods.

Fürst [1] found that the feeding of guinea pigs exclusively on plant seeds would produce scorbutus, although not so easily and regularly as exclusively grain feeding. Plant seeds that produced scurvy acquired antiscorbutic properties when infected with fungi. He concluded from his experiments that neither the ash nor any of its alkalis plays any part in the incidence of scorbutus. There was no apparent connection between the fat, alkali, carbohydrate, cellulose or enzymes in the food and the appearance of the disease.

Hart [2] was able to produce scorbutus, characteristic in both its symptoms and pathological anatomy, by feeding monkeys exclusively on trade condensed milk. They were kept in such good surroundings that they did not become rachitic. Control animals fed on a mixed diet did not develop scurvy. His results were confirmed by Dodd.[3]

Heubner and Lippschultz [4] fed dogs for many weeks on a

[1] Zeit. f. Hyg. u. Infectionskrankheiten, 1912, lxxii, 121.
[2] Virchow's Archiv. f. path. Anat. u. Phys., 1912, ccviii, 367.
[3] Boston Medical and Surgical Journal, 1913, clxix, 237.
[4] Quoted by Hart: Virchow's Arch. f. path. Anat. u. Phys., 1912, ccviii, 367.

food poor in phosphorus and found microscopic changes in the bones very similar to those found in scorbutus.

The results of these experiments hardly justify any very positive conclusions as to the cause of scurvy. They show very definitely, however, that scurvy is not due to starvation and that it is not brought on simply by the long-continued use of a single article of food. They suggest very strongly that when scurvy develops as the result of the continuous use of a single food, the trouble with the food is not that it contains some substance which causes scurvy but that it lacks some substance which prevents scurvy. They also seem to show that this substance which prevents scurvy is partially or wholly destroyed by drying and heating. They do not show whether this hypothetical substance is a single definite entity or a group of substances, closely related to each other and similar in their action.

The Metabolism in Scorbutus.—Very little is known as to the metabolism in scurvy. The only accurate study on the metabolism of scorbutus in adults is that of Baumann and Howard [1] who found that the loss of the various food constituents through the feces was less when fruit juice was added to the diet. The total sulphur metabolism was abnormal throughout the experiment, the quantity eliminated being in excess of that ingested. Chlorine and sodium were retained during the fruit juice period, but were excreted in excess of the intake during the preliminary period. More potassium, calcium and magnesium were retained during the fruit juice period than during the preliminary period. Lusk and Kloeman [2] studied the metabolism of nitrogen and the mineral salts in a typical case of scurvy in an infant eighteen months old. Observations were made for three periods of four days each; the first while the disease was at its height and the child was not being treated; the second, after a month's treatment; and the third, a month later, after all symptoms had disappeared. The nitrogen balance was normal at all times. The balance of mineral salts, particularly of calcium, was somewhat increased in the first period; in the second period during convalescence it was markedly decreased; and in the third period was approaching, but had not reached, the normal, although the child was clinically well. This is in decided contrast to the condition in rickets. These studies, while interesting, show nothing, however, as to the etiology of this disease.

The Vitamins.—Funk has recently called attention to the

[1] Archives of Internal Medicine, 1912, ix, 665.
[2] Jahrb. f. Kinderheilkunde, 1912, lxxv, 663.

significance of the so-called vitamins in physiology and pathology, especially in relation to the etiology of what he calls the "avitaminoses," namely, beriberi, scorbutus, pellagra and rickets.[1] He believes, and advances strong evidence to prove, that these diseases are due to the absence of certain vital substances in the food, that is, the vitamins. He shows from his own work and that of others that milk contains a considerable number of these antiscorbutic substances as well as a substance which materially favors the growth of young animals. The development of scurvy in infants taking foods which contain no milk may be explained, therefore, by assuming that these foods do not contain the essential vitamins which milk does contain. The vitamins are, in general, very sensitive to heat. Those in milk are relatively stable. They are, however, partially destroyed by heating milk for a short time, and totally destroyed by long heating or sterilization. The development of scurvy in babies taking heated milk and the greater frequency of the disease when the food is boiled or sterilized than when it is pasteurized may be explained by assuming that the vitamins are partially or wholly destroyed by the heating, the destruction being more or less complete according to the degree and duration of the heating. Scurvy sometimes develops, however, in babies that are taking raw milk, or even in those that are on the breast. His explanation of the development of scurvy on a diet of raw milk is that in such instances the milk is deficient in vitamins. In support of this explanation he brings forward evidence to show that the amount of the vitamins in the milk varies with the amount of the vitamins in the food of the cows. An example of the influence of the food of the cows upon the amount of vitamins in the milk is the fact that their milk contains less vitamins in the winter, when they are eating dry food, than in the summer, when they are eating green food. The development of scurvy in infants on the breast may be explained in a similar way. He calls attention to the fact, moreover, that the vitamins are diminished in the milk of women who are underfed.

Many objections can be raised to Funk's arguments and it may be urged that his premises are incorrect and his conclusions consequently not justified. Nevertheless, his proposition that scurvy is caused by the diminution or absence of certain essential vital elements, or vitamins, in the food, reconciles and explains the clinical facts and experimental evidence as to the etiology of this disease better than any other which has been advanced.

[1] Casimir Funk. Die Vitamine, etc., Wiesbaden: J. F. Bergman, 1914.

TREATMENT

There is nothing in the pathological changes, in the causes underlying the hemorrhagic condition, or in the results obtained from studies of the metabolism in this disease which yields any information of value as to its treatment. The clinical and experimental evidence all goes to show, however, that the disease is due to the lack of some essential element or elements in the food, probably belonging to the class of vitamins. This same evidence also shows that these elements are likely to be deficient in foods which do not contain milk. It shows, too, that they are present in milk and that they are weakened or destroyed when milk is heated, the effect of the heating apparently depending on the degree of heat and the duration of the heating. They are almost invariably present in sufficient quantities in human milk.

The indications furnished by this evidence as to the preventive treatment of scurvy are obvious. Babies should be nursed, whenever this is in any way possible. If the supply of breast-milk is insufficient, they should be given all that there is in order to make up for any possible deficiency in the antiscorbutic elements in the artificial food. If it is necessary to use an artificial food, the basis of this food should be milk, which contains antiscorbutic elements. Unless the use of raw milk is for some reason contraindicated, the milk should be given raw, because heating milk almost certainly weakens its antiscorbutic properties. If it is necessary to heat the milk, it should be pasteurized at the lowest temperature consistent with safety, in order that these properties may be weakened as little as possible. If it is necessary to use heated milk continuously, antiscorbutics should be given in addition. Babies should not be given foods for any considerable length of time which do not contain milk.

It has been known for many years that fresh vegetables and fruits contain elements which cure scurvy. The antiscorbutic properties of fruits are in general greater than those of vegetables. These properties are present in the fruit juices. Fruit juices can be easily given to babies; vegetable and vegetable juices are less suitable for them. The most available fruit juices are those of the lemon and orange. Babies prefer the taste of orange juice to that of lemon juice and it is less likely to disturb the digestion. Orange juice should be used, therefore, in the treatment of scurvy, if it is easily procurable. It should be given in doses of one ounce daily. Less than this amount is liable to be ineffective, and experience has shown that more than this is unnecessary. It is

best given in one dose, one hour before a feeding, when the stomach contains but little milk. It is less likely to disturb the digestion if given in this way. There is no objection to diluting it with water or to adding cane sugar to it, if the babies object to it plain. The boiling of orange juice does not lessen its therapeutic value. It does not, however, increase it. There is, therefore, no object in boiling it. The juice of the orange peel also contains antiscorbutic elements.[1] The only reason for using it instead of orange juice is for the sake of economy.

Since orange juice and lemon juice are so easily procurable, and since they are probably the most powerful antiscorbutics, it hardly seems necessary to consider vegetables and other fruits, even though they also will cure scurvy. An exception may perhaps be made in the case of potato, which is easily procured and inexpensive. The potato should be boiled and mashed and given in doses of at least a tablespoonful daily. Hess and Fish [2] have suggested the use of potato water instead of the cereal waters in the preparation of foods for infants as a preventive of scurvy.

Scurvy can also be cured by a change in the character of the food. Human milk will cure scurvy. The substitution of a food containing milk for one which does not or stopping the heating of the milk will usually cure it. Recovery is slow under these circumstances, however, while it is very rapid when orange juice is given. It is inadvisable, therefore, to trust to a change in the food to cure the disease. Orange juice will cure it, even if the food which caused the scurvy is continued. It is wiser, however, to change the food unless there is some special reason in connection with the baby's digestive capacity for continuing it.

Cod-liver oil and olive oil do not either prevent or cure scurvy. There are no drugs which have any influence upon it.

[1] Hess and Fish: Amer. Jour. Dis. of Children, 1914, viii, 385.
[2] *Loc. cit.*

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Printed in United States of America.